

## **APPENDIX B**

### **RESULTS FROM WORK PLAN ACTIVITIES**

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## LIST OF TERMS

bgs	below ground surface
PPlc	lower Plio-Pleistocene
PPlz	upper Plio-Pleistocene
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
S&T	Science and Technology
WMA	waste management area



## B.1.0 INTRODUCTION

Several field characterization studies were completed to increase understanding of the vadose zone contamination as it presently exists in waste management area (WMA) S-SX. The results of those studies are summarized in this appendix. The primary information obtained from those activities was that resulting from extensive analyses of soil samples taken from several boreholes in the WMA (Figure B.1). Those boreholes were as follows.

- **Borehole 41-09-39** – Lies southwest of tank SX-108 and was extended from 40 m (130 ft) below ground surface (bgs) to groundwater. This borehole was extended to further characterize soil contamination caused by a tank SX-108 leak. It was extended from the depth it was drilled to support a previous characterization effort to determine the extent of tank fluid migration in that location and to determine groundwater impacts. Further discussion of borehole 41-09-39 soil sampling and analyses is provided in Section B.2.0.
- **Borehole 299-W23-19** – Lies just southwest of tank SX-115. This borehole was drilled from the surface to groundwater to further characterize vadose zone contamination caused by a SX-115 leak and to determine groundwater impacts from the leak. Further discussion of borehole 299-W23-19 soil sampling and analyses is provided in Section B.3.0.
- **Tank SX-108 Slant Borehole** – A slanted hole was driven underneath tank SX-108. This borehole was drilled into the Plio-Pleistocene unit to characterize soils as near to the source of the tank SX-108 leak as possible and to investigate contaminant behavior underneath that tank. Further discussion of borehole SX-108 soil sampling and analyses is provided in Section B.4.0.
- **Boreholes 299-W22-48 and 299-W22-50** – Borehole 299-W22-48, located east of S tank farm, and borehole 299-W22-50, located southeast of SX tank farm, are *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring wells. These boreholes are close enough to the tank farms to be considered representative of tank farm vadose zone soils. Because the soils have not come into contact with tank fluids, their characteristics provide a means of defining tank farm vadose zone soil characteristics prior to tank leaks. Further discussion of boreholes 299-W22-48 and 299-W22-50 soil sampling and analyses is provided in Section B.5.0.

The characterization information summarized in this appendix includes brief descriptions of borehole geology, geophysical logs, moisture contents, soil suction data, soil water chemistry, and groundwater contamination data, if appropriate. In the interest of brevity, data reported here are those which have the most direct bearing on potential contaminant characteristics and migration. More background information is available in the referenced documents (Serne et al. 2001a,b,c,d).

In addition to the boreholes drilled and characterization of borehole samples, a shallow soils cone penetrometer study was completed around tank S-104 in the S tank farm to characterize near-surface contamination in that area. Further discussion of that study is provided in Section B.6.0.

**Figure B.1. Locations of Boreholes Sampled in Waste  
Management Area S-SX Characterization Studies**

Insert Figure B.1.

## B.2.0 BOREHOLE 41-09-39 CHARACTERIZATION

This section summarizes data reported in *Geologic and Geochemical Data Collected from Vadose Zone Sediments from Borehole SX 41-09-39 in the S/SX Waste Management Area and Preliminary Interpretations* (Serne et al. 2001b) except for the groundwater sample data which are reported in *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX (November 1997 through April 2000)* (Johnson and Chou 2001). Borehole 41-09-39 was completed to further characterize the nature and extent of vadose zone contamination from the tank SX-108 leak. The data reported here are a follow-on from a previous drilling and sampling program (Myers et al. 1998) in which the borehole was drilled down to 40 m (130 ft) bgs. In the recent study the borehole was extended to groundwater, and soil samples were taken and analyzed from 40 m (130 ft) bgs to 68.6 m (225 ft) bgs. Also, sidewall coring samples were collected between 8 and 40 m (25 and 130 ft) bgs as the borehole was being decommissioned. Extensive analyses of these sediment samples were also completed. The method used to advance and sample this borehole may have contributed to cross-contamination of portions of each sample interval. Core was taken to recognize and minimize the impact of these occurrences for this field investigation report.

The most significant data provided by this characterization effort were measurements on sediment samples for radionuclides and chemicals attributed to the tank SX-108 leak. Elevated concentrations of several constituents were primarily measured in soils between 19 and 40 m (61 and 130 ft) bgs. This depth interval includes the Hanford formation H1 and H2 subunits. The primary radionuclides present in this zone are cesium-137 and technetium-99. Maximum cesium-137 concentrations are present in subunit H1 between 20 and 25 m (65 and 83 ft) and at lesser amounts in subunit H2 between 25 and 30 m (83 and 108 ft). The presence of high levels of cesium-137 at borehole 41-09-39 is indicative of strong lateral movement of tank fluid and attributed to unusually high cesium-137 mobility shortly after release from tank SX-108. Maximum technetium-99 concentrations are present in the subunit H2 between 24 and 39 m (79 and 129 ft). The primary chemical characteristics attributed to tank fluid-soil interaction within this zone are elevated pH, sodium, chromium, and nitrate. The depth of maximum technetium-99 concentration coincides with high nitrate concentrations and marks the leading edge of vertical tank fluid migration in the direction measurable in this borehole.

The measured moisture contents are somewhat dry relative to undisturbed Hanford formation soils. Soil suction measurements suggest that drainage is occurring in the soil column but the measured soil suction variability is too high to quantify rate of drainage. The lack of tank fluid contaminants below the Plio-Pleistocene unit and the low concentrations of technetium-99, and nitrate in groundwater samples from borehole 41-09-39 supports the hypothesis that contaminants from this area may not have reached the unconfined aquifer.

## B.2.1 GEOLOGY AT BOREHOLE 41-09-39

Borehole 41-09-39 was originally installed to a depth of 39.8 m (130.5 ft) bgs in December 1996. The borehole was installed by advancing a thick-walled casing with a sealed, hardened drive point using a pile driver. No samples could be collected or analyzed due to the nature of this original construction. Subsequently, the drive point was milled-off and the borehole deepened to groundwater. A cable-tool drilling rig was used to deepen and collect

samples to 68.6 m (225 ft) bgs. Split-spoon samples were collected whenever possible. Borehole decommissioning was subsequently completed in 1999 by grouting the void space to eliminate a potential preferential pathway for contaminant migration. During decommissioning of this borehole, side-wall sediment samples were collected from preselected horizons in the upper, previously unsampled portion of the bore. The nature of the side-wall sampler precluded collection of any coarse grained materials during decommissioning.

#### **B.2.1.1 Hanford formation**

No Hanford formation samples were collected during the original construction of borehole 41-09-39. In addition, the sediment samples collected using the side-wall sampler during decommissioning were unsuitable for geologic interpretation. Samples that were collected were biased toward fine-grained materials due to the nature of the sampling device.

#### **B.2.1.2 Plio-Pleistocene Unit**

The top of the Plio-Pleistocene unit is not identified in this borehole. The first samples collected during the extension were from the upper Plio-Pleistocene (PPlz) subunit. The lower Plio-Pleistocene (PPlc) subunit was also present.

- **Subunit PPlz** – Subunit PPlz is interpreted to be present from the start of sampling at 39.8 m (130.5 ft) bgs to about 47.5 m (155.8 ft) bgs. The upper sampled sediments consist of a very fine-grained sequence that is a thin-bedded, up to 0.3 m (1 ft) thick, silty very fine-grained sand to silt. The graded silty sand to silt beds appear to become thicker and more massive with depth. Beds in the middle portion of the sequence are on the order of 1 m (3 ft) thick and about 1.5 m (5 ft) thick at the bottom. The sand ranges from moist to dry and friable. Some silt stringers up to 1 cm (0.4 in.) thick were observed. Two massively bedded silt to clayey silt units are present; one from 43.5 to 44.2 m (142.8 to 144.9 ft) bgs and a second from 46 to 47.3 m (151 to 155 ft) bgs. The upper unit is described as moist with a strong to weak reaction to hydrogen chloride. It is a massively bedded clayey silt to silt at the base, grading upward to a silty sand, then back to a silt at the top. The lower silt to clayey silt layer is described as very compacted. Some small stratifications of very fine-grained sand with limonitic staining are present. The base of the PPlz subunit is dominated by a well-sorted 20 cm (8 in.) thick fine sand.
- **Subunit PPlc** – Subunit PPlc is approximately 1.3 m (4.3 ft) thick extending to approximately 48.6 m (160 ft) bgs. This horizon ranges in grain size from sandy silt to sandy gravel. It is moderately to strongly cemented with pinkish to whitish calcium carbonate. In places the calcium carbonate cement is massive, forming a calcrete layer that was broken up during drilling. In other places the calcium carbonate appears disseminated into the sand or silt matrix or as coatings on the gravel clasts.

#### **B.2.1.3 Ringold Formation**

The Ringold Formation consists predominately of weakly cemented sandy gravel to strongly cemented matrix-supported conglomerate and is correlated with the member of Wooded Island unit E.

The gravel-conglomeritic facies is both clast supported and matrix supported. The matrix ranges from a sandy mud to muddy fine sand to well-sorted quartz-rich fine or medium sand to very

coarse sand. Gravel clasts are subrounded to rounded and range up to 70 mm (2.8 in.). The clasts are predominately composed of quartzite, basalt, and granite. In places the basalt and granitic clasts are highly weathered and limonitic staining is common.

Intercalated sand and silt-mud lenses are common. These minor strata range in thickness from a few centimeters to nearly 1 m (3 ft). The sand units range from silty fine to very fine sand to clean, well-sorted fine or medium quartz sand to poorly sorted, gravelly, muddy, coarse- to fine-grained sand.

Silty and muddy units are generally poorly sorted and consist of slightly gravelly sandy silt to gravelly mud. Two thin (6 to 24 cm [2 to 9 in]), clean mud units were observed at 61.6 m (202.2 ft) bgs and 63.3 m (207.5 ft) bgs.

## **B.2.2 GEOPHYSICAL AND PHYSICAL PROPERTY MEASUREMENTS AT BOREHOLE 41-09-39**

Downhole geophysical measurements at borehole 41-09-39 included a cadmium zinc tellurium gross gamma log and a drilling resistance log down to 40 m (130 ft) bgs, high-purity germanium spectral gamma logs from 40 m (130 ft) bgs to groundwater (about 65 m [214 ft] bgs), and neutron-neutron logs over the entire depth. Geophysical data for between 8 and 40 m (25 and 130 ft) bgs and between 40 and 65 m (130 and 214 ft) bgs are shown in Figures B.2 and B.3, respectively. The geophysical data provide features that distinguish stratigraphic units in the vadose zone. Subunit H1 shows a high gross gamma count because of the high cesium-137 content and a high drilling resistance because of the high gravel content. The Plio-Pleistocene unit shows relatively high natural thorium-232 and uranium-238 levels and moisture content.

Laboratory measurements of soil moisture content (Table B.1 and Figure B.4) show similar trends in relative concentrations as the neutron-neutron moisture measurements. Matric potential values were also measured (Figure B.5). While the majority of the data are indicative of a draining profile, a number of measurements suggest upward flow. Serne et al. (2000b) attributes this to the drying effect resulting from the head loading imposed by the contents of tank SX-108. The data variability is not indicative of unit gradient conditions nor does it provide any indication of deep drainage.

## **B.2.3 SOIL WATER CHEMISTRY MEASUREMENTS**

In addition to soil physical property measurements (Section B.2.2), an extensive water chemistry analysis has been completed for borehole 41-09-39 samples collected between 8 and 65 m (25 and 215 ft) bgs. The primary means of measuring porewater composition was to add deionized water to soil samples to generate enough water for performing analyses. By back-calculating for the dilution introduced by the added water, 'true' concentrations were derived. For a few samples porewater was directly separated from the same soil sample or one nearby and analyzed directly. By comparing the dilution-corrected water extract data with the porewater data in these few samples, an indication of the closeness of the water extract chemistry to original water chemistry was determined. In general, comparisons were not exact but concentration values were generally within a factor of two or better, agreement improved with increasing constituent concentration, and both sets of data showed similar concentrations versus soil depth correlations. Thus, the water extract method is an effective tool for evaluating tank fluid interactions with vadose zone soil.

**Figure B.2. Gamma-Ray, Drilling Resistance, and Moisture Logs  
for the Upper Portion of Borehole 41-09-39**

Insert Figure B.2.

**Figure B.3. Detailed Lithology and Analytical Values of Split-Spoon  
Samples from the Lower Portion of Borehole 41-09-39**

Insert Figure B.3.

**Table B.1. Moisture Content (wt%) of Borehole 41-09-39  
Sidewall Cores and Extension Sleeves (2 Sheets)**

Depth (ft bgs)	Sample ID	Moisture Content (%)	Depth (ft bgs)	Sample ID	Moisture Content (%)	Depth (ft bgs)	Sample ID	Moisture Content (%)
<b>Sidewall</b>			149.9	8B	9.7	183.9	36C	3.37
25.5	15A/B/C	8.12	151.1	9C	12.8	184.6	36B	2.06
44.5	14A/B/C	8.57	151.8	9B	NM	185.8	37D	1.39
56.5	13A/B/C	16.27	152.8	9A	13.9	186.2	37C	2.6
61.5	12A/B/C	12.84	153.4	10C	13.6	186.8	37B	2.35
65.5	11A/B	4.71	153.9	10B	14.7	187.2	37A	2.09
66	11C	5.29	154.5	10A	19.6	187.8	38C	2.87
69.5	10A/B/C	4.36	155.1	11D	5.4	188.3	38B	1.9
74.5	9A/B/C	5.17	155.4	11C	4.3	188.7	38A	1.8
79.5	8A/B/C	10.71	155.9	11B	3.5	189.2	39B	1.54
82.5	7A/B/C	8.41	156.4	11A	4.5	189.5	39A	1.93
90	6A/B	10.25	156.8	12B	6.9	190.7	40A	5.13
95.5	3A/B/C	7.83	157.1	12A	6.6	193.3	45A	5.28
102.5	5A/B/C *	10.4	157.2	13D	6.4	195.9	47D	8.84
108.5	4A/B/C	12.01	157.7	13C	4	196.4	47C	6.62
112	2B/C	8.17	158.2	13B	5.3	196.9	47B	5.74
127.4	1A/B/C	12.66	159.4	14C	5.9	197.4	47A	4.94
<b>Extension</b>			160	14B	5.8	199.1	49B	8.25
131.1	1C	NM	160.6	14A	7.6	199.1	49A	9.53
131.7	1B	13	162.3	16D	13.3	199.4	50B	6.83
133.2	2D	35.6	162.8	16C	13.5	199.4	50A	3.89
133.7	2C	18.3	163.3	16B	4.1	200.2	52B	5.47
133.7	2C-2	26.7	163.8	16A	4.4	200.7	52A	8.15
134.2	2B	14.5	164.3	17D	4.91	202.5	54B	6.58
134.7	2A	16	164.8	17C	3.56	202.5	54A	5.44
135.9	3A	13.1	165.3	17B	5.27	204.3	56C	7.74
137.4	4C	10.9	165.8	17A	4.91	205	56B	6.58
138	4B	11.7	166.6	18C	9.7	205.6	56A	5.44
138.7	4A	16.1	167.1	18B	4.7	207.6	58D	9.4
139.9	5D	14.1	167.7	18A	4.7	208.1	58C	10.18
140.3	5C	14.5	169.9	20A	4.3	208.6	58B	10.57



**Table B.1. Moisture Content (wt%) of Borehole 41-09-39  
Sidewall Cores and Extension Sleeves (2 Sheets)**

Depth (ft bgs)	Sample ID	Moisture Content (%)	Depth (ft bgs)	Sample ID	Moisture Content (%)	Depth (ft bgs)	Sample ID	Moisture Content (%)
140.9	5B	12.6	171.3	22C	5.8	209	58A	8.16
141.5	5A	9.4	172	22B	5.2	209.4	59D	10.1
141.9	6F	11	178.2	28A	7.94	209.8	59C	12.49
142.4	6E	9.6	178.8	30C	6.9	210.4	59B	17.5
143.3	6D	21.8	179.2	30B	3.35	210.9	59A	24.97
144.1	6C	26	179.7	30A	3.11	211.7	62B	8.15
144.7	6B	22.9	180.2	31B	4.36	212.1	62A	10.03
145.2	7E	8.7	180.5	31A	3.72	212.9	64B	12.58
145.8	7D	9.5	181.1	32B	5.31	213.3	64A	13.19
146.4	7C	11.2	181.5	32A	3.15	214.1	65B	7.76
146.4	7C-R	11.2	183	35B	3.56	214.3	65A	8.6
148.3	8C	7.4	183.3	35A	2.84			

\* One of the three cores may be different depth at 5A/B/C.

NM = not measured.

**Figure B.4. Moisture Content (wt%) versus Depth for  
Vadose Sediments from Borehole 41-09-39**

Insert Figure B.4.

**Figure B.5. Soil Suction Profile for Samples Taken from Borehole 41-09-39**

Insert Figure B.5.

Water extract pH and electrical conductivity measurements with depth are listed in Table B.2 and graphed in Figure B.6. Elevated pH values (8.5 to 9.7) are measured between 20 and 25 m (65 and 83 ft) bgs primarily in subunit H1 of the Hanford formation. Because pH values are expected to decrease as increasing interaction with soil and soil water occurs, the location of maximum pH values suggests the approximate initial depth of tank fluid interaction with the vadose zone at this location. Increases in electrical conductivity values compared to undisturbed soil water values are also an indicator of tank fluid occurrence in soil. Substantive increases are measured between 20 and 40 m (65 and 132 ft) bgs with maximum values (approximately 98,000 to 524,000  $\mu\text{S}/\text{cm}$ ) between 25 and 39 m (83 and 127 ft) bgs, primarily in subunit H2. Maximum electrical conductivity values are an indicator of location for mobile tank fluid constituents and maximum vertical penetration of tank fluids along the pathway sampled at this location.

Water extract anion concentrations as a function of depth are listed in Table B.3. Nitrate, chloride, and sulfate concentrations with depth are shown in Figure B.7. The primary indicator of tank fluid occurrence is elevated nitrate concentrations which is measured in this borehole between 20 and 41 m (65 and 136 ft) bgs with maximum values between 25 and 39 m (83 and 127 ft) bgs. Elevated levels of chloride (between 25 and 39 m [83 and 127 ft] bgs) and sulfate (between [20 and 39 m [65 and 127 ft] bgs) are also observed. Chloride maximum concentrations (between 27 and 34 m [90 and 112 ft] bgs) track closely with nitrate in subunit H2. An isolated chloride peak occurs at 60 m (197 ft) bgs, which may be a residual from groundwater present when the water table was elevated and has since drained. The sulfate peak occurs between 25 and 34 m (83 and 112 ft) bgs. The sulfate peak occurs between 25 and 34 m (83 and 112 ft) bgs, a maximum concentration depth interval that also coincides with chloride and nitrate. Also, sulfate shows a slight increase in concentration at 56 and 58 m (185 and 189 ft) bgs where the isolated chloride peak occurred in the Ringold Formation. Between 56 and 58 m (185 and 189 ft) bgs represents the high groundwater elevation.

Water extract cation concentrations as a function of depth are listed in Table B.4 and graphed in Figure B.8. Among the cations, elevated sodium concentrations are the primary tank fluid indicator. Maximum values begin abruptly at 25 m (83 ft) bgs and remain elevated above 10,000 mg/L until 34 m (112 ft) bgs. Calcium, magnesium, potassium, and natural strontium show depleted concentrations at 19 to 24 m (61 to 80 ft) bgs and above the high sodium zone and show elevated concentrations between 27 and 39 m (90 and 127 ft) bgs, a depth range coincident and perhaps slightly ahead of the high sodium range. The relative positioning of sodium concentration ranges versus that of the other cations supports the hypothesis that sodium preferentially replaces these cations in sorption sites as it migrates vertically and pushes them ahead to the leading edge of a leak plume.

The last group of constituents analyzed included radionuclides and trace metals. Of these, cesium-137, technetium-99, and chromium (Tables B.5 and B.6) are clearly present in concentrations above background and are attributed to have originated in the tank fluid. Water extract concentrations of cesium-137 are listed in Table B.5 and distribution is shown in Figure B.9. Above-background cesium-137 concentrations are measured between 8 and 42 m (25 and 137 ft) bgs.

**Table B.2. Measurements of pH and Electrical Conductivity for 1:1 Water Extracts of Borehole 41-09-39 Sidewall and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )
<b>Sidewall</b>														
25.5	15A/B/C	8.39	188	2317	141.9	6F	8.49	255	4886	165.3	17B	7.77	149	2828
44.5	14A/B/C	8.52	226	2638	142.4	6E	8.36	203	4389	165.8	17A	7.78	93.0	2031
56.5	13A/B/C	8.31	287	1790	143.3	6D	8.46	300	3033	166.6	18C	8.10	181	1861
61.5	12A/B/C	8.61	355	2767	144.1	6C	8.29	353	3057	167.1	18B	7.85	99.0	2100
65.5	11A/B	9.18	899	19092	144.7	6B	8.5	314	3036	167.7	18A	7.94	105	2246
66	11C	9.76	504	9535	145.2	7E	8.75	194	2328	169.9	20A	8.35	216	5033
69.5	10A/B/C	9.18	752	17248	145.8	7D	8.7	212	2209	171.3	22C	8.43	250	4295
74.5	9A/B/C	9.60	719	13928	146.4	7C	8.41	237	2097	172.0	22B	8.33	180	3433
79.5	8A/B/C	9.55	1722	16090	148.3	8C	8.71	236	3160	178.2	28A	8.46	231	2897
82.5	7A/B/C	8.70	8293	98684	149.9	8B	8.71	200	2032	178.8	30C	8.36	183	2637
90	6A/B	8.33	41820	408017	152.8	9A	8.91	210	1489	179.2	30B	7.62	67.0	2000
95.5	3A/B/C	7.93	41010	521060	153.4	10C	8.75	277	1997	179.7	30A	7.72	74.0	2375
102.5	5A/B/C	8.01	41910	402855	153.9	10B	8.7	254	2085	180.2	31B	8.42	214	4892
108.5	4A/B/C	8.07	56480	470722	154.5	10A	8.75	221	1085	180.5	31A	8.39	201	5395
112	2B/C	8.12	42770	524413	155.4	11C	8.62	163	3736	181.1	32B	8.51	267	5044
127.4	1A/B/C	7.92	16550	130789	155.9	11B	8.64	155	4431	181.5	32A	8.30	151	4793
<b>Extension</b>					156.4	11A	8.67	114	4788	183.0	35B	8.50	261	7334
131.1	1C	8.52	382	N/A	156.8	12B	8.64	379	5435	183.3	35A	8.32	190	6680
131.7	1B	8.06	4858	36192	157.1	12A	8.63	317	4761	183.9	36C	8.18	137	4052
133.2	2D	8.26	865	1817	157.2	13D	8.55	289	4471	184.6	36B	7.85	67.0	3247

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**Table B.2. Measurements of pH and Electrical Conductivity for 1:1 Water Extracts of  
Borehole 41-09-39 Sidewall and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )
133.7	2C	8.28	413	1648	157.7	13C	8.8	311	7731	185.0	36A	7.96	94.0	5493
134.2	2B	8.36	658	4363	158.2	13B	8.7	190	3576	185.8	37D	7.87	68.0	4891
134.7	2A	8.25	611	3629	158.7	13A	7.21	207	3912	186.2	37C	7.48	49.0	1886
135.2	3B	8.25	831	5618	159.4	14C	8.5	270	4552	186.8	37B	7.66	40.0	1699
135.9	3A	8.34	442	3266	160	14B	8.46	215	3726	187.2	37A	7.57	45.0	2155
137	4D	8.29	387	3150	160.6	14A	8.38	189	2482	187.8	38C	8.16	121	4201
137.4	4C	8.78	172	1538	162.3	16D	8.28	245	1813	188.3	38B	7.75	58.0	3046
138	4B	8.61	223	1846	162.8	16C	8.52	319	2313	188.7	38A	7.35	24.0	1337
138.7	4A	8.63	193	1141	163.3	16B	8.02	117	2828	189.2	39B	7.95	79.0	5131
140.3	5C	8.57	230	1520	163.8	16A	7.79	92	2112	189.5	39A	8.11	123	6379
140.9	5B	8.92	184	1417	164.3	17D	8.36	268	5435	190.7	40A	7.77	59.0	1147
141.5	5A	8.97	167	1737	164.8	17C	8.31	322	9000	193.3	45A	8.79	275	5239
195.9	47D	8.23	93.0	1048										
196.4	47C	8.16	101	1523										
196.9	47B	7.40	71.0	1243										
197.4	47A	7.70	76.0	1546										
198.8	49C	8.22	165	1838										
199.1	49B	8.17	149	1803										
199.1	49A	8.13	152	1605										
199.4	50B	8.22	165	2412										
199.4	50A	7.81	102	2631										

**Table B.2. Measurements of pH and Electrical Conductivity for 1:1 Water Extracts of  
Borehole 41-09-39 Sidewall and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )	Depth (ft bgs)	Sample ID	1:1 extract pH	1:1 extract ( $\mu\text{S}/\text{cm}$ )	Corrected ( $\mu\text{S}/\text{cm}$ )
200.2	52B	8.45	160	2928										
200.7	52A	8.33	148	1814										
202.5	54B	8.08	135	2067										
202.5	54A	7.96	93.0	1721										
204.3	56C	7.94	86.0	1082										
205	56B	8.16	122	1479										
205.6	56A	8.07	94.0	1208										
207.6	58D	8.26	191	2034										
208.1	58C	8.30	160	1576										
208.6	58B	7.87	60.0	569										
209	58A	7.56	42.0	513										
209.4	59D	8.06	103	1017										
209.8	59C	7.72	56.0	452										
210.4	59B	7.72	55.0	316										
210.9	59A	8.80	710.	284										
211.7	62B	7.81	50.0	610										
212.1	62A	7.73	51.0	512										
212.9	64B	8.04	92.0	1122										
213.3	64A	7.99	76.0	762										
214.1	65B	7.85	87.0	1124										
214.3	65A	7.93	72.0	838										

**Figure B.6. Concentrations of pH, Electrical Conductivity, and  
Nitrate in Dilution-Corrected Water Extract**

Insert Figure B.6.



**Table B.3. Anion Concentrations at Borehole 41-09-39 in 1:1 Water Extracts (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 Extracts					Dilution Factor	Dilution Ratio Corrected				
		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)
Sidewall												
25.5	15A/B/C	13.0	<0.3	NM	0.26	1.70	12.3	161	<4.0	NM	3.18	20.9
44.5	14A/B/C	13.0	0.92	NM	0.26	16.4	11.7	152	10.7	NM	3.01	191
56.5	13A/B/C	13.0	0.84	NM	0.26	<2.8	6.24	81.0	5.22	NM	1.61	<17.2
61.5	12A/B/C	13.0	0.81	NM	0.26	5.13	7.79	102	6.34	NM	2.01	40.0
65.5	11A/B	29.1	0.52	NM	0.26	11.5	21.2	618	10.9	NM	5.48	244
66.0	11C	17.6	0.26	NM	0.26	6.45	18.9	333	4.89	NM	4.88	122
69.5	10A/B/C	33.5	0.38	NM	0.26	8.66	22.9	767	8.80	NM	5.91	199
74.5	09A/B/C	44.3	0.54	NM	0.26	18.1	19.4	857	10.5	NM	5.00	351
79.5	08A/B/C	371	3.34	NM	1.40	51.7	9.34	3464	31.3	NM	13.1	483
82.5	07A/B/C	2836	30.1	NM	82.1	336	11.9	33746	358	NM	976	3999
90.0	06A/B	28044	307	NM	139	271	9.76	273614	2992	NM	1355	2642
95.5	03A/B/C	32767	321	NM	28.6	260	12.7	416332	4074	NM	364	3308
102.5	05A/B/C	31666	198	NM	133	198	9.61	304385	1903	NM	1279	1904
108.5	04A/B/C	42448	359	NM	130	386	8.33	353773	2990	NM	1084	3215
112.0	02B/C	32764	344	NM	106	373	12.3	401733	4212	NM	1297	4576
127.4	01A/B/C	12808	77.5	NM	28.6	73.3	7.90	101213	613	NM	226	579
Extension												
134.2	2B	291	NM	NM	NM	NM	6.63	1929	NM	NM	NM	NM
134.7	2A	268	NM	NM	NM	NM	5.94	1592	NM	NM	NM	NM
135.2	3B	362	NM	NM	NM	NM	6.76	2447	NM	NM	NM	NM
135.9	3A	165	NM	NM	NM	NM	7.39	1219	NM	NM	NM	NM

**Table B.3. Anion Concentrations at Borehole 41-09-39 in 1:1 Water Extracts (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 Extracts					Dilution Factor	Dilution Ratio Corrected				
		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)
Extension (Cont'd)												
137.4	4C	12.0	NM	NM	NM	NM	8.94	107	NM	NM	NM	NM
138	4B	24.0	NM	NM	NM	NM	8.28	199	NM	NM	NM	NM
140.3	5C	9.90	NM	NM	NM	NM	6.61	65.4	NM	NM	NM	NM
140.9	5B	3.70	NM	NM	NM	NM	7.70	28.5	NM	NM	NM	NM
141.5	5A	9.80	NM	NM	NM	NM	10.4	102	NM	NM	NM	NM
141.9	6F	9.10	NM	NM	NM	NM	19.2	174	NM	NM	NM	NM
142.4	6E	14.0	NM	NM	NM	NM	21.6	303	NM	NM	NM	NM
143.3	6D	42.0	NM	NM	NM	NM	10.1	425	NM	NM	NM	NM
144.1	6C	58.0	NM	NM	NM	NM	8.66	502	NM	NM	NM	NM
144.7	6B	48.0	NM	NM	NM	NM	9.67	464	NM	NM	NM	NM
145.2	7E	18.0	NM	NM	NM	NM	12.0	216	NM	NM	NM	NM
145.8	7D	32.0	NM	NM	NM	NM	10.4	333	NM	NM	NM	NM
146.4	7C	36.0	NM	NM	NM	NM	8.85	319	NM	NM	NM	NM
152.8	9A	24.0	NM	NM	NM	NM	7.09	170	NM	NM	NM	NM
153.4	10C	48.0	NM	NM	NM	NM	7.21	346	NM	NM	NM	NM
153.9	10B	49.0	NM	NM	NM	NM	8.21	402	NM	NM	NM	NM
154.5	10A	33.0	NM	NM	NM	NM	4.91	162	NM	NM	NM	NM
155.4	11C	9.80	NM	NM	NM	NM	22.9	225	NM	NM	NM	NM
155.9	11B	8.40	NM	NM	NM	NM	28.6	240	NM	NM	NM	NM
156.4	11A	5.30	NM	NM	NM	NM	42.0	223	NM	NM	NM	NM
156.8	12B	10.5	NM	NM	NM	NM	14.3	151	NM	NM	NM	NM

**Table B.3. Anion Concentrations at Borehole 41-09-39 in 1:1 Water Extracts (3 Sheets)**

Depth (ft bgs)	Sample ID	1:1 Extracts					Dilution Factor	Dilution Ratio Corrected				
		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)		Nitrate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrite (ppm)	Sulfate (ppm)
Extension (Cont'd)												
157.1	12A	7.50	NM	NM	NM	NM	15.0	112	NM	NM	NM	NM
157.2	13D	2.00	NM	NM	NM	NM	15.5	30.9	NM	NM	NM	NM
157.7	13C	6.20	NM	NM	NM	NM	24.9	154	NM	NM	NM	NM
158.2	13B	6.80	1.00	0.45	<0.06	14.5	18.8	128	18.8	8.50	<1.1	273
162.8	16C	1.90	NM	NM	NM	NM	7.25	13.8	NM	NM	NM	NM
163.3	16B	4.60	NM	NM	NM	NM	24.2	111	NM	NM	NM	NM
163.8	16A	6.70	NM	NM	NM	NM	23.0	153	NM	NM	NM	NM
164.8	17C	0.30	NM	NM	NM	NM	28.0	8.4	NM	NM	NM	NM
165.3	17B	7.60	NM	NM	NM	NM	19.0	144	NM	NM	NM	NM
165.8	17A	10.8	NM	NM	NM	NM	21.8	236	NM	NM	NM	NM
172	22B	5.00	3.00	1.40	<0.06	13.0	19.1	95.4	57.2	26.7	1.10	248
179.2	30B	4.70	1.30	0.38	<0.04	4.70	29.9	140.	38.8	11.3	1.20	140
184.6	36B	3.00	1.60	0.52	<0.06	3.70	48.5	145.	77.5	25.2	<2.9	179
189.2	39B	0.80	2.40	0.56	<0.06	3.40	65.0	51.3	155	36.4	<3.9	221
196.9	47B	18.0	110	0.21	<0.06	2.50	17.5	315.	1926	3.70	<0.5	43.8
200.2	52B	<0.10	3.70	0.81	<0.06	22.0	18.3	<1.8	67.7	14.8	<1.1	403
208.6	58B	0.60	1.50	0.48	<0.06	2.50	9.49	5.20	14.2	4.6	<0.6	23.7
211.7	62B	0.60	1.00	0.48	<0.06	2.70	12.2	7.70	12.2	5.9	<0.7	32.9
214.1	65B	<0.10	1.50	0.45	<0.06	5.50	12.9	<1.29	19.4	5.8	<0.8	71.1

**Figure B.7. Dilution-Corrected 1:1 Sediment to Water Extract Anions and Actual  
Porewater Anion Concentrations versus Lithology and Depth**

Insert Figure B.7.

**Table B.4. Major Cation Composition of 1:1 Water Extracts from  
Borehole 41-09-39 Sidewall Cores and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	Calcium (ppm)	Potassium (ppm)	Magnesium (ppm)	Sodium (ppm)	Strontium (ppm)	Aluminum (ppm)	Boron (ppm)	Iron (ppm)	Manganese (ppm)	Silicon (ppm)
<b>Sidewall</b>											
25.5	15A/B/C	9.30	6.40	1.10	29.5	(0.053)	0.84	5.20	0.51	(0.01)	21.5
44.5	14A/B/C	6.00	6.90	0.70	41.8	(0.049)	0.59	15.9	0.14	(0.01)	14.8
56.5	13A/B/C	22.4	7.40	2.00	43.2	(0.036)	0.51	5.30	<0.25	<0.05	9.30
61.5	12A/B/C	3.60	2.60	0.30	80.7	(0.042)	0.56	31.0	(0.05)	(0.01)	7.50
65.5	11A/B	1.10	(1.70)	0.40	121	(0.035)	1.48	9.00	2.03	(0.04)	14.2
66.0	11C	0.90	2.60	1.90	212	(0.051)	5.72	10.5	8.97	0.13	37.0
69.5	10A/B/C	0.80	3.60	1.00	176	(0.035)	3.08	4.50	4.27	0.08	24.0
74.5	9A/B/C	0.50	(2.40)	(0.10)	168	(0.047)	0.65	10.3	(0.11)	<0.05	12.5
79.5	8A/B/C	0.70	4.20	(0.10)	423	(0.057)	0.75	35.6	(0.02)	<0.05	5.30
82.5	7A/B/C	22.1	16.0	2.20	2041	0.46	(0.48)	16.9	(0.02)	<0.05	7.00
90.0	6A/B	142	209	7.20	11270	2.68	(0.37)	26.6	(0.04)	<0.05	3.00
95.5	3A/B/C	975	129	19.8	10209	15.1	(0.22)	12.4	(0.06)	<0.05	3.60
102.5	5A/B/C	563	128	24.1	10753	10.1	(0.20)	14.0	(0.08)	<0.05	3.70
108.5	4A/B/C	449	117	17.3	15256	8.76	(0.26)	8.30	(0.08)	<0.05	4.80
112.0	2B/C	453	81.2	23.7	11344	8.56	<0.50	30.2	(0.06)	<0.05	4.90
127.4	1A/B/C	1705	76.7	186	1921	13.6	<0.50	15.7	(0.04)	0.10	5.10
<b>Extension</b>											
134.2	2B	49.3	5.38	12.9	31.3	0.22	<0.05	1.82	<0.05	<0.05	4.60
134.7	2A	57.4	4.29	13.8	22.5	0.26	<0.05	0.45	<0.05	<0.05	6.00
135.2	3B	57.3	22.4	15.0	53.6	0.26	<0.05	1.86	<0.05	0.06	7.90
135.9	3A	39.2	(10.7)	8.18	23.4	0.14	<0.05	0.77	<0.05	0.06	4.20

**Table B.4. Major Cation Composition of 1:1 Water Extracts from  
Borehole 41-09-39 Sidewall Cores and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	Calcium (ppm)	Potassium (ppm)	Magnesium (ppm)	Sodium (ppm)	Strontium (ppm)	Aluminum (ppm)	Boron (ppm)	Iron (ppm)	Manganese (ppm)	Silicon (ppm)
Extension (Cont'd)											
137.4	4C	19.7	(1.60)	3.13	10.8	0.06	<0.05	0.29	<0.05	<0.05	5.00
138.0	4B	20.0	(8.10)	3.98	14.8	0.06	<0.05	0.37	<0.05	<0.05	5.40
140.3	5C	16.0	(3.20)	3.62	19.0	0.06	<0.05	0.50	<0.05	<0.05	6.60
140.9	5B	21.8	(6.60)	3.21	14.2	0.07	<0.05	0.41	<0.05	<0.05	4.70
141.5	5A	17.8	(2.40)	3.24	(13.5)	0.07	<0.05	0.34	<0.05	<0.05	6.30
141.9	6F	19.7	4.07	6.07	19.3	0.09	<0.05	1.45	<0.05	<0.05	9.70
142.4	6E	13.4	4.83	4.18	15.0	0.07	-0.06	0.99	<0.05	<0.05	10.0
143.3	6D	20.3	5.08	7.21	19.9	0.09	<0.05	0.54	<0.05	<0.05	10.7
144.1	6C	25.3	7.24	9.17	25.2	0.13	(0.07)	0.67	<0.05	<0.05	12.3
144.7	6B	22.4	5.15	8.09	22.0	0.1	<0.05	0.72	<0.05	<0.05	11.3
145.2	7E	12.1	(2.50)	3.88	17.5	0.05	(0.08)	1.23	<0.05	<0.05	11.2
145.8	7D	13.1	(2.90)	4.26	18.9	0.06	(0.14)	1.98	<0.05	<0.05	13.5
146.4	7C	15.3	(3.80)	5.53	20.1	0.08	(0.06)	1.26	<0.05	<0.05	14.3
151.1	9C	15.0	5.02	4.94	16.1	0.07	(0.07)	1.29	<0.05	<0.02	9.90
151.8	9B	13.2	4.63	4.45	15.6	0.06	<0.05	0.93	<0.05	<0.05	10.4
152.8	9A	10.5	4.62	3.63	16.3	0.05	0.17	1.09	<0.05	<0.01	9.80
153.4	10C	13.4	7.14	5.70	20.0	0.07	<0.05	0.84	<0.05	<0.05	10.1
153.9	10B	13.7	4.22	6.36	17.6	0.06	0.18	1.42	(0.07)	<0.01	16.4
154.5	10A	13.0	5.64	5.06	16.3	0.06	0.19	1.20	<0.05	<0.05	14.7
155.4	11C	12.5	(4.60)	3.60	12.1	0.04	<0.05	0.79	(0.04)	<0.01	15.1
155.9	11B	12.9	(3.60)	3.5	10.9	0.05	<0.05	0.94	<0.05	<0.05	14.9

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**Table B.4. Major Cation Composition of 1:1 Water Extracts from Borehole 41-09-39 Sidewall Cores and Extension Sleeves (3 Sheets)**

Depth (ft bgs)	Sample ID	Calcium (ppm)	Potassium (ppm)	Magnesium (ppm)	Sodium (ppm)	Strontium (ppm)	Aluminum (ppm)	Boron (ppm)	Iron (ppm)	Manganese (ppm)	Silicon (ppm)
<b>Extension (Cont'd)</b>											
156.4	11A	11.3	(3.40)	2.51	6.63	0.04	0.01	0.96	<0.05	<0.05	10.9
156.8	12B	12.1	8.16	4.43	49.6	0.06	<0.05	0.92	<0.05	<0.05	14.0
157.1	12A	11.2	6.89	4.11	40.3	0.06	<0.05	1.12	<0.05	<0.05	13.1
157.2	13D	13.4	11.2	4.74	50.8	0.06	<0.05	0.62	<0.05	<0.05	12.5
157.7	13C	12.6	7.34	3.73	35.1	0.06	(0.08)	0.99	(0.06)	<0.05	13.8
158.2	13B	11.3	(4.30)	3.63	16.7	0.05	0.13	0.93	(0.09)	<0.05	15.9
162.3	16D	5.77	5.94	2.14	33.8	(0.03)	(0.08)	1.26	0.07	0.07	7.60
163.3	16B	5.40	3.14	1.60	7.58	(0.03)	0.08	0.81	0.08	(0.01)	11.1
163.8	16A	2.83	1.97	0.97	7.53	(0.01)	0.35	1.37	0.33	(0.03)	15.2
164.3	17D	9.52	6.00	3.02	29.3	0.05	(0.12)	0.93	0.14	(0.04)	11.3
165.3	17B	2.53	(2.00)	0.92	9.35	(0.01)	0.35	1.39	0.45	(0.02)	16.6
165.8	17A	2.75	2.00	0.92	7.72	(0.01)	0.60	1.28	0.71	(0.03)	16.6

Note: Values in parenthesis are near the detection limit but are considered good values.

NM = not measured.

**Figure B.8. Dilution-Corrected Cation Concentrations at  
Borehole 41-09-39 in 1:1 Sediment to Water Extracts**

Insert Figure B.8.



**Table B.5. Cesium-137 Activity in Borehole 41-09-39 Sidewall Cores and Extension Sleeves (2 Sheets)**

Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)	Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)	Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)
		Wet Wt.	Error	Dry Wt.			Wet Wt.	Error	Dry Wt.			Wet Wt.	Error	Dry Wt.
Sidewall					151.8	9B	9.54E+01	1.83E+00	NM	183	35B	3.21E-01	5.49E-02	3.32E-01
25.5	15A/B/C	5.50E+02	9.70E+00	6.06E+02	152.8	9A	1.67E-01	1.24E-01	1.82E-01	183.3	35A	<MDA		<MDA
44.5	14A/B/C	1.01E+03	1.83E+01	1.11E+03	152.9	10D	1.12E+02	2.57E+00	NM	183.9	36C	1.75E-01	3.95E-02	1.81E-01
56.5	13A/B/C	2.36E+04	5.27E+02	2.60E+04	153.4	10C	7.13E-02	2.33E-02	7.95E-02	184.6	36B	4.89E-01	4.97E-02	4.99E-01
61.5	12A/B/C	1.13E+05	2.19E+03	1.25E+05	153.9	10B	<MDA		<MDA	185	36A	<MDA		NM
65.5	11A/B	5.68E+05	1.06E+04	6.26E+05	154.5	10A	1.98E-02	3.67E-02	2.39E-02	185.8	37D	1.57E-01	3.51E-02	1.59E-01
66	11C	3.71E+06	6.89E+04	4.09E+06	155.1	11D	1.75E+00	1.70E-01	1.84E+00	186.2	37C	<MDA		<MDA
69.5	10A/B/C	8.61E+03	1.10E+02	9.49E+03	155.4	11C	<MDA		<MDA	186.8	37B	<MDA		<MDA
74.5	9A/B/C	2.13E+06	3.94E+04	2.34E+06	155.9	11B	<MDA		<MDA	187.2	37A	<MDA		<MDA
79.5	8A/B/C	2.32E+06	4.54E+04	2.56E+06	156.4	11A	9.82E+00	2.94E-01	1.03E+01	187.8	38C	2.91E-01	3.23E-02	2.99E-01
82.5	7A/B/C	1.60E+07	4.31E+05	1.76E+07	156.8	12B	7.38E+01	1.16E-01	7.89E+01	188.3	38B	<MDA		<MDA
90	6A/B	3.97E+04	5.32E+02	4.38E+04	157.1	12A	7.31E+01	9.69E-01	7.79E+01	188.7	38A	<MDA		<MDA
95.5	3A/B/C	3.40E+04	4.66E+02	3.82E+04	157.2	13D	5.56E+01	7.80E-01	5.92E+01	189.2	39B	3.72E-01	4.12E-02	3.78E-01
102.5	5A/B/C	1.44E+06	2.83E+04	1.62E+06	157.7	13C	1.02E+01	2.45E-01	1.06E+01	189.5	39A	2.84E-01	3.72E-02	2.89E-01
108.5	4A/B/C	3.00E+05	7.54E+03	3.37E+05	158.2	13B	1.15E+00	7.46E-02	1.21E+00	190.7	40A	<MDA		<MDA
112	2B/C	1.32E+03	2.35E+01	1.49E+03	158.7	13A	3.13E-01	3.83E-02	NM	193.3	45A	4.40E-01	4.72E-02	4.63E-01
127.4	1A/B/C	3.73E+03	6.40E+01	4.20E+03	159	14D	NM		NM	195.9	47D	6.34E-02	1.87E-02	6.90E-02
Extension					159.4	14C	2.68E+00	1.08E-01	2.84E+00	196.4	47C	<MDA		<MDA
131.1	1C-L	3.24E+05	4.79E+03	NM	160	14B	<MDA		<MDA	196.9	47B	<MDA		<MDA
131.1	1C-D	7.96E+04	1.21E+03	NM	160.6	14A	<MDA		<MDA	197.4	47A	1.92E-02	6.11E-03	2.01E-02
131.7	1B-1	2.08E+06	3.58E+04	2.35E+06	162.3	16D	2.24E+00	8.25E-02	2.49E+00	198.8	49C	<MDA		NM
131.7	1B-2	9.29E+02	1.41E+01	NM	162.8	16C	2.28E+00	1.04E-01	2.61E+00	199.1	49B	1.65E-01	3.23E-02	1.79E-01
133.2	2D	4.80E+04	6.44E+02	6.50E+04	163.3	16B	4.56E+00	3.03E-02	4.75E+00	199.1	49A	9.66E-02	2.60E-02	1.06E-01
133.7	2C	2.66E+04	4.09E+02	3.15E+04	163.8	16A	<MDA		<MDA	199.4	50B	2.49E-01	6.19E-02	2.66E-01
133.7	2C-2	1.16E+06	1.70E+04	1.47E+06	164.3	17D	1.86E+00	8.63E-02	1.95E+00	199.4	50A	<MDA		<MDA
134.2	2B	2.27E+03	3.25E+01	2.60E+03	164.8	17C	9.31E-01	6.17E-02	9.63E-01	200.2	52B	<MDA		<MDA
134.7	2A	5.73E+01	1.14E+00	6.65E+01	165.3	17B	6.46E-02	2.98E-02	6.32E-02	200.7	52A	2.06E-01	3.55E-02	2.23E-01

**Table B.5. Cesium-137 Activity in Borehole 41-09-39 Sidewall Cores and Extension Sleeves (2 Sheets)**

Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)	Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)	Depth (ft bgs)	Sample ID	Cesium-137 (pCi/g)	Cesium-137 (+/- pCi/g)	Cesium-137 (pCi/g)
		Wet Wt.	Error	Dry Wt.			Wet Wt.	Error	Dry Wt.			Wet Wt.	Error	Dry Wt.
135.2	3B	2.29E+03	4.04E+01	NM	165.8	17A	<MDA		<MDA	202.5	54B	4.85E-02	3.93E-02	5.17E-02
135.9	3A	2.93E+03	3.79E+01	3.31E+03	166.1	18D	3.42E-01	8.96E-02	NM	202.5	54A	2.18E-02	1.27E-02	2.30E-02
137.0	4D	NM		NM	166.6	18C	<MDA		<MDA	204.3	56C	<MDA		<MDA
137.4	4C	<MDA		<MDA	167.1	18B	<MDA		<MDA	205	56B	1.04E-01	5.05E-02	1.11E-01
138.0	4B	4.31E+01	6.62E-01	4.81E+01	167.7	18A	5.12E-02	6.11E-02	5.24E-01	205.6	56A	3.45E-02	1.31E-02	3.64E-02
138.7	4A	4.76E-01	6.19E-02	5.86E-01	169.2	20D	1.60E+00	7.94E-02	NM	207.6	58D	5.27E-02	2.07E-02	5.77E-02
139.9	5D	3.63E+01	5.34E-01	4.14E+01	169.4	20C	1.42E+00	1.14E-01	NM	208.1	58C	1.03E-01	3.93E-02	1.13E-01
140.3	5C	1.54E+01	3.11E-01	1.76E+01	169.7	20B	1.75E+00	8.73E-02	NM	208.6	58B	<MDA		<MDA
140.9	5B	6.93E+01	1.06E+00	7.81E+01	169.9	20A	2.94E-01	3.37E-02	3.02E-01	209	58A	<MDA		<MDA
141.5	5A	3.61E+00	1.50E-01	3.97E+00	171.3	22C	4.81E-01	7.19E-02	5.08E-01	209.4	59D	<MDA		<MDA
141.9	6F	1.39E+02	2.92E+00	1.54E+02	172	22B	4.19E-01	3.98E-02	4.42E-01	209.8	59C	<MDA		<MDA
142.4	6E	2.69E+00	1.57E-01	2.96E+00	172.7	22A	<MDA		NM	210.4	59B	<MDA		<MDA
143.3	6D	1.10E-01	3.69E-02	1.34E-01	178.2	28A	5.78E-01	6.25E-02	6.24E-01	210.9	59A	<MDA		<MDA
144.1	6C	1.38E+02	2.99E+00	1.74E+02	178.8	30C	5.39E-01	8.53E-02	5.76E-01	211.7	62B	2.87E-02		3.10E-02
144.7	6B	<MDA		<MDA	179.2	30B	<MDA		<MDA	212.1	62A	<MDA		<MDA
145.2	7E	4.21E+00	1.48E-01	4.57E+00	179.7	30A	<MDA		<MDA	212.9	64B	4.01E-02	3.37E-02	4.51E-02
145.8	7D	2.06E-01	2.05E-01	2.19E-01	180.2	31B	6.53E-01	8.02E+00	6.81E-01	213.3	64A	2.39E-02	1.18E-02	2.71E-02
146.4	7C	<MDA		<MDA	180.5	31A	5.18E-01	7.34E-02	5.37E-01	214.1	65B	2.31E-01	3.52E-02	2.49E-01
148.3	8C	2.04E+01	3.96E+00	2.19E+01	181.1	32B	6.25E-01	1.07E-01	6.58E-01	214.3	65A	9.05E-02	2.62E-02	9.83E-02
149.9	8B	1.27E+01	2.99E-01	1.39E+01	181.5	32A	1.53E-01	2.87E-02	1.58E-01	215	67*	1.13E-01	9.25E-02	NM
151.1	9C	1.09E+03	2.17E+01	1.23E+03										

Note: Sleeves 1C and 1B were partially filled and were compressed materials from the pile driving of the original casing. 1C-L and 1C-D represent light and dark compressed sediments. 1B-1 and 1B-2 were two distinctly different grain-sized compressed materials. 2C-2 was a fine-grained lens of silt within a fine sand matrix.

67\* = clean out material in saturated sediments.

MDA = Minimum detectable cesium-137 activity; less than 2.00E-02 pCi/g.

NM = not measured.

**Figure B.9. Cesium-137 Activity in Sediment versus Lithology and Depth**

Insert Figure B.9.

**Table B.6. Trace Metal Composition of 1:1 Water Extracts and Porewaters  
from Borehole 41-09-39 Sidewall Cores and Extension Composites (2 Sheets)**

Composite Depth (ft bgs)	1:1 Extract ID	ICP-MS							
		Technetium-99 (pCi/L)	Chromium (ppb)	Cobalt (ppb)	Nickel (ppb)	Zinc (ppb)	Arsenic (ppb)	Selenium (ppb)	Molybdenum (ppb)
Sidewall									
25.5	15A/B/C	<1.0E+03	<0.5	(3.00)	<100	(68.0)	26.0	<5	14.0
44.5	14A/B/C	<1.0E+03	(2.89)	(1.00)	<100	(65.0)	14.9	<5	74.6
56.5	13A/B/C	<1.0E+03	(3.47)	<50	<100	(53.0)	0.77	<5	62.6
	13 UFA	2.88E+05	6463	<83	(9.00)	109	(4.33)	44.7	104
61.5	12A/B/C	7.0E+02	(8.15)	(3.00)	<100	(56.0)	4.00	<5	24.9
65.5	11A/B	4.1E+03	344	(2.00)	(4.00)	(104)	24.3	<5	304
66	11C	7.8E+03	342	(1.00)	(2.00)	(102)	15.8	<5	93.4
69.5	10A/B/C	5.5E+03	5070	(7.00)	<100	(86.0)	30.0	<5	516
74.5	09A/B/C	7.7E+03	4091	(5.00)	(4.00)	(51.0)	24.3	<5	552
79.5	08A/B/C	1.8E+04	718	(1.00)	(2.00)	(49.0)	7.84	(4.86)	1003
	8 UFA	5.17E+05	20850	<156	(11.0)	1848	(8.13)	(74.2)	2596
82.5	07A/B/C	3.9E+05	745753	96.0	(6.0)	(66.0)	7.63	85.7	6378
90	06A/B	2.7E+06	711595	86.0	(6.0)	(88.0)	<5	135	2911
	6 UFA	2.48E+07	5627500	<453	(41.0)	944	264	1218	5032
95.5	03A/B/C	7.1E+06	260333	(30.0)	<100	(83)	<5	219	427
102.5	05A/B/C	6.1E+06	527799	60.0	<100	(112)	<5	228	1575
108.5	04A/B/C	1.2E+07	481344	63.0	(5.00)	(60)	<5	388	604
	4 UFA	9.40E+07	3183229±23128	259±17	29±13	235±9	628±19	2836±62	943±27
112	02B/C	8.6E+06	175630	25.0	<100	(50)	<5	288	17.0
	2 UFA	1.23E+08	1795521	(157)	(41.0)	(332)	685	3074	(102)

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**Table B.6. Trace Metal Composition of 1:1 Water Extracts and Porewaters from Borehole 41-09-39 Sidewall Cores and Extension Composites (2 Sheets)**

Composite Depth (ft bgs)	1:1 Extract ID	ICP-MS							
		Technetium-99 (pCi/L)	Chromium (ppb)	Cobalt (ppb)	Nickel (ppb)	Zinc (ppb)	Arsenic (ppb)	Selenium (ppb)	Molybdenum (ppb)
127.4	01A/B/C	3.3E+05	11.47	(0)	<100	(89)	1.05	31.5	167
<b>Extension*</b>									
133.2	2C/D	1000± 2500	3.00	6.86	<5	32.0	NA	<10	121
134.2	2A/B	5650±2200	<0.5	<0.5	<5	7.00	NA	<10	15.2
135.2	3A/B	2720±2500	<0.5	<0.5	<5	22.0	NA	<10	58.0
153.9	10A/B	3900±5200	<0.5	<0.5	<5	11.0	NA	<10	31.1
156.8	12A/B	380±2900	<0.5	<0.5	<5	7.00	NA	<10	87.1
165.3	17A/B	9320±12800	<0.5	<0.5	<5	14.0	NA	<10	13.0
188.3	38A/B	50±2800	<0.5	<0.5	<5	6.00	NA	<10	22.0
196.9	47A/B	(-190)±4700	<0.5	<0.5	<5	13.5	NA	<10	11.7
208.6	58A/B	(-470)±3800	<0.5	<0.5	<5	10.2	NA	<10	9.80

\*For technetium-99 the borehole extension samples were analyzed by wet chemical separations and liquid scintillation counting. Samples were analyzed in duplicate and mean and uncertainty are presented. The deepest two composites yielded negative values. The technique is not as sensitive as the ICP-MS data. Units for technetium-99 are pCi/L and not mass units.

Highlighted pairs are chemical analyses of soil water derived from a common soil in two ways, by 1:1 water extraction and by direct removal of porewater by centrifugation using the unsaturated flow apparatus (UFA).

ICP = inductively coupled plasma.

MS = mass spectrometer.

NA = not analyzed.

The primary zone of true contamination is considered to be in subunit H1 and the upper half of subunit H2 between 18 and 39 m (60 and 127 ft) bgs. In this zone three peaks occur at 20, 25, and 31 m (66, 82.5, and 102 ft) bgs at concentration levels of  $4 \times 10^6$ ,  $2 \times 10^7$ , and  $2 \times 10^6$  pCi/g. Overall, the vast majority of cesium-137 mass resides in subunit H1 between 20 and 26 m (66 and 84 ft) bgs. Just below these peaks, cesium-137 concentrations drop by orders of magnitude.

The primary zone of elevated technetium-99 concentration (listed as pCi/L in Table B.6) lies between 24 and 39 m (79 and 127 ft) bgs, where maximum concentrations of greater than  $1 \times 10^7$  pCi/L are measured at 33 m (108 ft) bgs. Water extract concentrations of technetium-99 with depth are shown in Figure B.10. This pattern closely mimics the nitrate concentration distribution. Chromium concentration values increase above background beginning at 20 m (66 ft) bgs and reach maximum concentrations of greater than 100,000  $\mu\text{g/L}$  between 22 and 38 m (82 and 112 ft) bgs. The occurrence of the maximum chromium range slightly higher in the soil column relative to technetium-99 indicates some retarding chemical mechanism has slowed chromium migration relative to technetium-99. Work completed by the Hanford Science and Technology (S&T) Program (Appendix D, Section D.4.1) indicates that iron(II)-rich minerals in the vadose zone soil reduce the oxidation state of a fraction of the chromium in solution from +6 to +3. In the +3 state, chromium is removed from solution by sorption or co-precipitation in iron(II)-rich minerals.

## B.2.4 CHEMICAL INTERACTIONS

No specific experiments were completed on soils from borehole 41-09-39 to quantify geochemical reactions influencing contaminant migration. Dominant chemical reactions affecting radionuclides and tank fluid chemicals are inferred from the relative location of these constituents in the soil column, comparison of acid-leachable versus water-leachable concentrations for specific contaminants, and general knowledge of the tank fluid chemistry. Greater contaminant mobility is inferred from the occurrence of high concentration zones deeper in the vadose zone and smaller differences in dissolved concentrations leached by water versus acid.

Generally speaking, the data suggest that tank SX-108 fluid chemistry had a substantial but limited effect on contamination behavior at borehole 41-09-39. Given the distance between borehole 41-09-39 and the tank SX-108 bottom, the presence of very high concentrations of cesium-137 in subunit H1 in this borehole shows that cesium-137 was initially highly mobile in the leaked tank fluid. Various types of sorption experiments completed by the S&T activity (Appendix D, Section D.3.0) shows that the very high concentrations of cesium-137, sodium and to a lesser extent potassium in the tank SX-108 fluid created local conditions where sodium preferentially occupied soil sorption sites in soils and preventing cesium-137 sorption. These conditions were short-lived and confined to subunit H1 and the top part of subunit H2 as shown by the current limited distribution of cesium-137. Over time natural infiltration and recharge subsequently separated sodium from cesium-137, permitting cesium-137 to sorb in situ. The current degree of cesium-137 mobility was determined by comparing the amount of cesium-137 removed by water versus total activity measured by gamma. The in situ distribution coefficient for cesium-137 varies from 4 to 25 mL/g in the sediments between 27 and 34 m (90 and 112 ft) bgs where the bulk of the tank fluid with high salinity resides. Above and below this depth range cesium-137 in situ distribution coefficient values are usually much larger (greater than 1000 mL/g) because the pore fluids do not contain high sodium concentrations that compete for adsorption sites.

**Figure B.10. Technetium-99 Activity in Porewater in Borehole 41-09-39**

Insert Figure B.10.

Tank fluids also increased amounts of other constituents to the soil column but had little effect on the chemical behavior of contaminants other than cesium-137 in the sense that chemical reactions between tank fluid constituents and the soil column environment were largely controlled by soil-soil water reactions. Constituent anions (e.g., nitrate and technetium-99) have migrated the most rapidly and mark the leading edge of vertical tank fluid migration. The technetium-99 in situ distribution coefficient was determined by comparing acid versus water leached concentrations and varies from 0.01 to about 5 mL/g over the whole zone of contamination. Chromium was slightly retarded relative to technetium-99 and nitrate, presumably because of oxidation reduction, allowing fixation on soil. Generally, the in situ distribution coefficient values were negative except for the soil sample at 24 m (80 ft) bgs where the distribution coefficient value greater than 20 mL/g was estimated.

Other constituent cations have migrated varying distances depending on the strength of retardation mechanisms. Sodium concentrations, being relatively high, successfully competed for sorption sites in vadose zone soils, were somewhat retarded. Calcium, magnesium, and indigenous strontium were displaced by sodium and pushed ahead of sodium during migration.

### **B.2.5 GROUNDWATER MEASUREMENTS**

One sample of groundwater was taken from borehole 41-09-39 prior to decommissioning. Small concentrations of technetium-99, tritium, and nitrate are present in the water. There is no indication of a tank waste source. A more likely source is the upgradient crib 216-S-25.



### B.3.0 BOREHOLE 299-W23-19

This section summarizes data reported in *Geologic and Geochemical Data Collected from Vadose Zone Sediments from Borehole 299-W23-19 [SX-115] in the S/SX Waste Management Area and Preliminary Interpretations* (Serne et al. 2001c) except for the groundwater sample data, which are reported in the RCRA groundwater quality assessment report (Johnson and Chou 2001). Borehole 299-W23-19 was completed to further characterize the nature and extent of vadose zone contaminants supplied by a tank SX-115 leak. The most significant data provided by this characterization effort were soil measurement of radionuclides and chemicals attributed to the tank SX-115 leak. Elevated concentrations of several constituents were primarily measured in soils between 22 and 48 m (73 and 156 ft) bgs. This depth interval includes subunits H1 and H2 and subunit PPlz. The primary radionuclide present in this zone is technetium-99. Cesium-137 is present in very small concentrations at the top of this contaminated soil zone. The primary chemical characteristics attributed to tank fluid-soil interaction at different locations within this zone are elevated pH, sodium, chromium, nitrate, and chloride.

The absence of tank fluid constituents in the PPlc subunit of the Plio-Pleistocene unit and the Ringold Formation down to the water table is significant because of the very high technetium-99 content in the first water samples taken from borehole 299-W23-19. Subsequent conversion of this borehole into a monitoring well and continued groundwater sampling has revealed sustained high technetium-99 content. Also, the technetium-99/nitrate ratios at this well are indicative of a tank waste source because they are significantly greater than ratios in surrounding wells (Figure C.25) indicating a different source that is enriched in technetium-99. Also, the well ratio values (0.11 pCi/ $\mu$ g or 110 pCi/mg) are essentially the same as the ratio values in water extract data from soil samples in the high technetium-99/nitrate zone of borehole 299-W23-19 (Table 3.5). Assuming that both vadose zone and groundwater contamination from this borehole come from the tank SX-115 leak, a complicated migration path is indicated which must include both lateral and vertical movement.

Moisture content and matric potential measurements are consistent with recent high recharge through the soil column at this location imposed by one or more leaking water lines. Moisture contents are generally above average in the soil column and matric suction measurements indicate drainage is occurring throughout the soil column. These data and the presence of contaminants in other wells downgradient of tank SX-115 (Appendix C, Section C.7.0) present a logical pattern of accelerated migration of tank SX-115 fluid contaminants to and subsequent limited distribution within the unconfined aquifer.

### B.3.1 GEOLOGY

Borehole 299-W23-19 was drilled using air-rotary techniques. Samples were collected via the split spoon technique in as near-continuous manner as possible. The split-spoon samplers were driven into the formation ahead of the casing. After the samples were extracted from the hole, a standard bit was lowered in the hole and materials removed to the depth at which the sampling stopped. The casing was driven to that same depth and the process repeated. Samples were attempted in the Ringold Formation but the cemented gravels proved too much for the technique. Samples were collected from near the historic high groundwater elevation and again at the water table.

### B.3.1.1 Backfill

Backfill material extends from the surface to 18.7 m (61.5 ft) bgs. The material consists of non-cohesive sand with variable silt and minor pebbles. There was little variation in the geophysical logs of borehole 299-W23-19 confirming its relatively uniform nature.

### B.3.1.2 Hanford formation

All three Hanford formation subunits (H1a, H1, and H2) were present and sampled.

- **Subunit H1a** – Subunit H1a occurs from 18.7 to 23.8 m (61.5 to 78 ft) bgs in borehole 299-W23-19. The subunit consists of several upward fining, coarse sand to silty fine sand rhythmites. Sedimentary structures within these beds range from planar-laminated sand at the base to wavy ripple cross-laminated sand and silt at the top. Grain sizes within individual beds are gradational but the upper and lower boundaries of individual beds are sharp, where coarse sand associated with the overlying bed lies in direct contact with fine material from the underlying bed. Higher moisture is usually associated with the finer grained upper portions of these graded beds.
- **Subunit H1** – Subunit H1 occurs from 23.8 to 28.7 m (78 to 94 ft) bgs in borehole 299-W23-19. The subunit is predominantly a pebbly, medium- to coarse-grained sand. At least two layers of fine sand to muddy sand are present in the sequence.
- **Subunit H2** – Subunit H2 occurs from 28.7 to approximately 37.2 m (94 to 122 ft) bgs in borehole 299-W23-19. The subunit is predominantly fine grained, consisting of stratified fine sand to silty fine sand. Several coarser sand interbeds are present toward the top of the sequence. Graded rhythmites development is not as obvious in subunit H2 as in subunit H1a. Instead, there appear to be many irregular subtle gradations, mostly between platy (laminated), silty-fine to very-fine sand and occasionally medium to coarse sand. The calcium carbonate content of this unit is relatively low. Based on an increase in total gamma activity on geophysical logs the base of subunit H2 has been identified at 37.2 m (94 ft) bgs in an interval where there was no core recovery.

### B.3.1.3 Plio-Pleistocene Unit

The two Plio-Pleistocene unit subunits are the upper subunit PPlz, characterized by a relatively high silt content and the lower subunit PPlc, characterized by secondary, pedogenic, calcium-carbonate cement.

- **Subunit PPlz** – Subunit PPlz is interpreted to extend from 37.2 to 47.5 m (122 to 156 ft) bgs at borehole 299-W23-19. The subunit consists of mostly fine to very fine sand that is intercalated with silty fine sand to silt/clay. Most beds display well-preserved stratification, except within paleosols where the bedding has been disturbed by blocky soil-ped development, mottling, and/or bioturbation associated with pedogenesis. Dark carbonaceous aggregates (i.e., decomposed organic matter) and secondary iron-oxide and manganese-oxide staining are also common.

- **Subunit PPlc** – Subunit PPlc is interpreted to extend from 47.5 to 48.8 m (156 to 160 ft) bgs at borehole 299-W23-19. At this site subunit PPlc consists of weathered, dark-olive gray, loose, basaltic, pebbly sand interspersed with more indurated layers of mud and calcium carbonate. The geologic interpretation of this unit at this location differs from elsewhere in the vicinity of the SX tank farm. In this borehole the unit is highly basaltic and coarse in nature; elsewhere the unit is typically a massive carbonate facies. Additionally, the calcium carbonate does not occur as a single, well-developed caliche layer but appears to occur as stringers within the coarse-grained basaltic alluvium.

#### B.3.1.4 Ringold Formation

The remainder of the vadose zone at borehole 299-W23-19 below 48.8 m (160 ft) bgs is composed of Ringold Formation, member of Wooded Island, unit E as described in *Vadose Zone Geology of Boreholes 299-W22-50 and 299-W23-19-S-SX Waste Management Area Hanford Site, South-Central Washington* (Lindsey et al. 2000). The recovered materials consist predominately of fluvial, weakly cemented sandy gravel to strongly cemented, matrix-supported conglomerate. The gravel/conglomeratic facies is both clast supported and matrix supported. The matrix ranges from sandy mud, to muddy fine sand, to well-sorted quartz-rich fine or medium sand, to very coarse sand. The gravel clasts are subrounded to rounded and range up to 70 mm (3 in.) in diameter. The clasts are composed predominately of quartzite, basalt, and granite. In places, the basalt and granitic clasts are highly weathered, and iron oxide staining is common.

### B.3.2 GEOPHYSICAL AND PHYSICAL PROPERTY MEASUREMENTS

Downhole geophysical measurements included a high-purity germanium spectral gamma log, a neutron-neutron log, a neutron-gamma log, and a temperature log. The total gamma log (derived from the spectral gamma logs) and the neutron-neutron log are shown in Figure B.11. In borehole 299-W23-19 where negligible manmade gamma contamination is present, the gamma data track relative potassium-40 concentrations and higher potassium-40 concentrations indicate silt-rich layers. In this case the PPlz subunit contains maximum potassium-40 concentrations. The spike at 30 m (100 ft) bgs is considered to be an artifact of the measuring event, not a real indicator of high potassium-40 concentration. The neutron-neutron log shows qualitative relative moisture content and is consistent with laboratory-measured moisture contents shown in the adjacent column (moisture) and provided in Table B.7. The neutron-gamma log (not shown; see Lindsey et al. 2000) provides an indication of relative amounts of silica, calcium and hydrogen in the formation. A maximum temperature of 82 °F (28 °C) was measured at 20 m (65 ft) bgs, about the same depth as the tank bottom indicating that residual heat loading from the tank waste continues to have a local effect.

Soil suction measurements were completed for several soil samples. Soil suction values are plotted as a function of depth in Figure B.12. All values plot to the left of the drainage curve indicating that drainage is occurring in the soil column at borehole 299-W23-19. Conversely, in two RCRA groundwater monitoring wells east of WMA S-SX, where no indication of manmade discharge to the soil column is known to occur, drainage is not indicated for soil samples below the Plio-Pleistocene unit.

**Figure B.11. Borehole 299-W23-19 Lithology, Stratigraphy, and  
Moisture Content (wt%) Distribution as a Function of Depth**

Insert Figure B.11.

**Table B.7. Moisture Content of Sediments from Borehole 299-W23-19 (2 Sheets)**

Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)
01F	6.55	6.80	10C	36.35	9.42	18E	69.45	9.81	26E	102.95	7.04	31C	131.15	8.98	38F	152.60	13.47
01E	7.05	4.96	10B	36.85	9.15	18D	69.95	12.32	26D	103.45	3.79	31B	131.65	5.43	38E	153.10	14.07
01D	7.55	5.79	10A	37.35	8.38	18C	70.45	15.66	26C	103.95	6.99	31A	132.15	16.92	38D	153.60	15.96
01C	7.86	6.89	11F	40.85	6.20	18B	70.95	14.86	26B	104.45	8.99	32G	132.75	4.97	38C	154.10	17.95
01B	8.34	4.41	11E	41.35	6.51	18A	71.45	19.61	26A	104.95	6.81	32F	133.25	5.47	38B	154.60	19.15
01A	9.54	4.56	11D	41.85	8.18	19J	72.25	5.59	27J	105.55	21.03	32E	133.75	13.28	38A	155.10	26.11
03K	11.35	6.96	11C	42.35	11.00	19I	72.75	4.82	27I	106.05	12.76	32D	134.25	7.82	38	155.55	21.95
03J	11.85	7.49	11B	42.85	7.28	19H	73.25	3.61	27H	106.55	4.45	32C	134.75	8.60	39D	155.35	6.97
03I	12.35	7.59	11A	43.35	5.53	19G	73.75	12.15	27G	107.05	6.66	32B	135.25	13.33	39C	155.85	7.80
03H	12.85	6.81	13G	43.85	7.02	19F	74.25	14.11	27F	107.55	5.43	32A	135.80	17.27	39B	156.35	3.49
03G	13.35	7.18	13F	44.35	6.23	19E	74.75	14.20	27E	108.05	4.18	33I	136.65	9.81	39A	156.85	19.81
03F	13.85	7.45	13E	44.85	5.44	19D	75.25	12.92	27D	108.55	9.55	33H	137.15	13.86	40B	157.75	4.88
03E	14.35	5.73	13D	45.35	9.72	19C	75.75	6.05	27C	109.00	8.69	33G	137.65	15.57	40A	158.25	4.65
03D	14.85	7.25	13C	45.85	9.95	19B	76.25	3.84	27B	109.55	7.29	33F	138.15	9.90	40	158.65	10.12
03C	15.35	7.53	13B	46.35	8.80	19A	76.75	4.18	28G	110.25	8.42	33E	138.65	7.60	17SK	159.75	8.39
03B	15.85	5.13	13A	46.85	12.89	20H	78.25	3.32	28F	110.75	8.71	33D	139.15	4.95	18SKA	161	6.89
03A	16.35	5.99	14J	50.15	8.48	20G	78.75	5.26	28E	111.25	14.04	33C	139.65	7.99	18SKB	161.00	5.24
04H	17.15	5.07	14I	50.65	8.00	20F	79.25	7.32	28D	111.75	10.03	33B	140.15	15.49	18SKC	166.50	2.95
04G	17.65	5.63	14H	51.15	7.41	20E	79.75	12.58	28C	112.25	7.10	33A	140.65	11.49	19SKA	166.50	1.35
04F	18.15	7.24	14G	51.65	9.89	20D	80.25	16.67	28B	112.75	8.30	35K	141.05	11.47	19SKB	176.00	1.24
04E	18.65	6.86	14F	52.15	11.01	21E	82.00	2.58	28A	113.20	12.75	35J	141.35	13.24	41A	184.45	3.95
04D	19.15	7.26	14E	52.65	6.80	21D	83.00	3.55	29I	113.85	8.91	35I	141.85	24.48	19SKC	185	0.88
04C	19.65	8.72	14D	53.15	5.28	21C	84.00	4.31	29H	114.35	5.78	35H	142.35	27.23	20SKA	185	1.28
04B	20.15	7.94	15B	54.12	6.23	21B	85.00	2.94	29G	114.85	4.22	35G	142.85	27.15	20SKB	189.5	1.14

**Table B.7. Moisture Content of Sediments from Borehole 299-W23-19 (2 Sheets)**

Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)	Sample ID	Depth (ft bgs)	Moisture (%)
04A	20.65	7.25	15A	54.50	5.84	21A	86.00	2.89	29F	115.35	4.97	35F	143.35	26.00	42	194.55	5.87
05E	22.85	8.48	16B	56.95	6.59	22E	87.10	7.72	29E	115.85	5.51	35E	143.85	25.08	43B	204.50	6.16
05D	23.55	8.87	16A	57.45	6.32	22D	88.10	16.49	29D	116.35	5.60	35D	144.35	16.57	43A	205.15	2.70
05C	24.65	7.77	17J	61.75	5.33	22C	89.10	5.65	29C	116.85	9.08	35C	144.85	16.25			
05B	25.75	7.42	17I	62.25	5.70	22B	91.10	8.12	29A+B	117.85	9.87	35B	145.35	11.50			
05A	26.85	8.87	17H	62.75	5.18	22A	91.10	5.27	30G	123.85	7.86	35A	145.85	25.75			
08C	27.55	8.15	17G	63.25	8.99	24C	93.00	8.01	30F	124.35	10.12	36F	146.45	15.67			
08B	28.65	9.51	17F	63.75	11.77	24B	94.00	6.42	30E	124.85	10.07	36E	146.95	16.91			
08A	29.75	9.13	17E	64.25	21.84	24A	95.00	9.25	30D	125.35	9.78	36D	147.45	9.36			
09I	30.95	8.46	17D	64.75	20.18	25E	96.06	4.46	30C	125.85	13.18	36C	147.95	8.52			
09H	31.45	9.69	17C	65.25	11.13	25D	97.06	4.47	30B	126.35	16.57	36B	148.45	22.95			
09G	31.95	8.23	17B	65.75	10.30	25C	98.06	5.21	30A	126.85	13.86	36A	148.95	16.89			
09F	32.45	8.00	17A	66.25	9.34	25B	99.06	5.12	31J	127.80	12.27	37E	149.15	13.30			
09E	32.95	10.16	18K	66.45	13.04	25A	100.06	11.54	31I	128.15	7.26	37D	149.65	12.95			
09D	33.45	9.18	18J	66.95	14.17	26J	100.45	12.18	31H	128.65	11.59	37C	150.15	15.33			
09C	33.95	8.11	18I	67.45	17.48	26I	100.95	17.79	31G	129.15	15.12	37B	150.65	17.24			
09B	34.45	8.73	18H	67.95	16.46	26H	101.45	7.98	31F	129.65	16.32	37A	151.15	13.73			
09A	34.95	8.72	18G	68.45	5.16	26G	101.95	9.72	31E	130.15	15.09	38H	151.75	18.93			
10D	35.85	8.96	18F	68.95	9.88	26F	102.45	11.96	31D	130.65	12.30	38G	152.10	21.31			

**Figure B.12. Soil Suction Profiles for Borehole 299-W23-19**

Insert Figure B.12.

### B.3.3 SOIL WATER CHEMISTRY MEASUREMENTS

In addition to soil physical property measurements (Section B.3.2), an extensive water chemistry analysis has been completed for borehole 299-W23-19 samples collected between 10 and 62 m (32 and 205 ft) bgs. The primary means of measuring porewater composition was to add deionized water to soil samples to generate enough water for performing analyses.

By back-calculating for the dilution introduced by the added water, 'true' concentrations were derived. For a few samples porewater was directly separated from the same soil sample or one nearby and analyzed directly. By comparing the dilution-corrected water extract data with the porewater data in these few samples, an indication of the closeness of the water extract chemistry to original water chemistry was determined. In general, comparisons were not exact but concentration values were generally within a factor of two or better, agreement improved with increasing constituent concentration, and both sets of data showed similar concentrations versus soil depth correlations. Thus, the water extract method is an effective tool for evaluating tank fluid interactions with vadose zone soil.

Water extract pH and electrical conductivity measurements with depth are listed in Table B.8 and graphed in Figure B.13. Elevated pH values (greater than 8) are measured between 23 and approximately 32 m (75 and 105 ft) bgs with maximum values (8.5 to 9.7) occurring primarily in subunit H1 between 23 and 26 m (75 and 86 ft) bgs. Because pH values are expected to decrease as increasing interaction with soil and soil water occurs, the location of maximum pH values suggests the approximate initial depth of tank fluid interaction with the vadose zone at this location. Increases in electrical conductivity values compared to undisturbed soil water values are also an indicator of tank fluid occurrence in soil. Substantive increases are measured between 22 and 48 m (73 and 156 ft) bgs with maximum values (approximately 20,000 to 40,000  $\mu\text{S}/\text{cm}$ ) between 37 and 46 m (123 and 150 ft) bgs in the silt-rich subunit PPlz. Maximum electrical conductivity values are an indicator of location for mobile tank fluid constituents and maximum vertical penetration of tank fluids.

Water extract anion concentrations as a function of depth are listed in Table B.9 and graphed in Figure B.14. The primary indicator of tank fluid occurrence is elevated nitrate concentrations which are measured in borehole 299-W23-19 between 22 and 48 m (73 and 156 ft) bgs with maximum values between 38 and 46 m (125 and 150 ft) bgs. Elevated levels of chloride (between 22 and 62 m [73 and 205 ft] bgs) and sulfate (between 22 and 62 m [73 and 190 ft] bgs) are also observed. Chloride maximum concentrations (between 38 and 46 m [125 and 150 ft] bgs) track closely with the nitrate at the Plio-Pleistocene unit and above. However, an additional peak occurs in the Ringold Formation between 51 and 58 m (166 and 190 ft) bgs. The sulfate peak occurs between 22 and 38 m (73 and 125 ft) bgs, a maximum concentration depth interval that does not coincide with chloride and nitrate. A secondary sulfate peak range occurs in the Ringold Formation between 51 and 58 m (166 and 190 ft) bgs, coincident with the secondary chloride peak.

Elevated concentrations of these anions do not provide a straightforward indication of tank fluid occurrence. Elevated concentrations of chloride and sulfate extend well into the Ringold Formation (to groundwater in the case of chloride), unlike nitrate. This observation suggests other sources of chloride and sulfate (e.g., U pond water) which as late as 1986 elevated the water table up to 55 m (182 ft) bgs. In the Hanford formation and the Plio-Pleistocene unit, chloride and sulfate concentrations may come from the tank fluid or may result from some interaction between tank fluid nitrate and indigenous chloride and sulfate that preferentially dissolves these anions.



**Table B.8. Borehole 299-W23-19 Water Extract pH and Electrical Conductivity Values (2 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	1:1 pH	1:1 EC ( $\mu\text{S}/\text{cm}$ )	Pore EC ( $\mu\text{S}/\text{cm}$ )	Sample ID	Depth (ft bgs)	Dilution Factor	1:1 pH	1:1 EC ( $\mu\text{S}/\text{cm}$ )	Pore EC ( $\mu\text{S}/\text{cm}$ )
09E	32.95	9.85	7.94	166	1635	31A	132.15	6.36	6.95	5198	33066
15A	54.50	17.13	7.25	233	3992	32D	134.25	11.80	6.96	1658	19561
16A	57.45	15.82	7.27	226	3576	32A	135.80	5.79	6.8	4973	28781
17J	61.75	18.84	7.57	153	2883	33G	137.65	6.43	6.82	4860	31270
17G	63.25	11.13	7.52	186	2071	33B	140.15	6.45	6.81	4840	31238
17F	63.75	8.53	7.41	217	1851	35K	141.05	8.72	6.9	4593	40058
17F-dup	63.75	8.56	7.1	211	1807	35IH-aft	141.85	6.30	6.88	4265	26852
17DE-aft	64.75	10.70	7.48	206	2204	35F-aft	143.35	7.18	6.93	3264	23439
17C	65.25	9.03	7.32	160	1445	35C	144.85	6.15	6.95	2830	17409
18I	67.45	5.74	7.44	243	1394	35A	145.85	3.89	6.86	4315	16781
18E	69.45	10.19	7.62	226	2302	36D	147.45	10.20	6.98	1593	16254
18CB	70.45	6.56	7.91	431	2826	36B	148.45	4.35	7.02	2655	11562
18CB-dup	70.95	6.56	7.46	413	2709	37D	149.65	7.72	6.96	3792	29278
19H	73.25	27.70	8.61	603	16701	38G	152.10	4.32	7.21	979	4232
19G	73.75	7.49	8.33	1207	9038	38E	153.10	7.11	7.37	624	4439
19F	74.25	7.09	7.71	1248	8847	38E-dup	153.10	7.11	7.43	604	4297
19D	75.25	9.61	9.35	1039	9980	38A-aft	155.10	10.92	7.04	280	3057
20F	79.25	9.47	9.12	1094	10364	39D	155.35	9.49	7.39	768	7288
20F-dup	79.25	9.38	9.15	1025	9617	39C	155.85	12.83	6.83	352	4516

**Table B.8. Borehole 299-W23-19 Water Extract pH and Electrical Conductivity Values (2 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	1:1 pH	1:1 EC ( $\mu\text{S}/\text{cm}$ )	Pore EC ( $\mu\text{S}/\text{cm}$ )	Sample ID	Depth (ft bgs)	Dilution Factor	1:1 pH	1:1 EC ( $\mu\text{S}/\text{cm}$ )	Pore EC ( $\mu\text{S}/\text{cm}$ )
20E	79.75	7.79	9.28	1014	7902	39C-dup	155.85	12.82	6.97	342	4385
20D	80.25	6.00	8.5	1198	7184	40B	157.75	20.49	7.68	201	4119
21A	86.00	13.58	9.72	762	10350	40	158.65	10.96	7.65	297	3256
22D	88.10	6.07	7.79	1328	8056	17SK	159.75	11.92	7.7	281	3350
24A	95.00	10.82	7.91	1023	11065	18SKA	161	14.68	7.64	251	3684
25B	99.06	14.17	9.08	693	9822	18SKB	161.00	19.78	7.05	252	4984
25B-dup	99.06	15.85	8.74	595	9430	18SKC	166.50	34.13	7.26	148	5051
25A	100.06	11.40	7.83	1071	12212	19SKA	166.50	74.25	7.24	124	9207
26E	102.95	13.75	8.93	639	8786	19SKB	176.00	80.64	7.26	116	9354
26A	104.95	12.21	9.31	592	7226	41A	184.45	25.37	7.9	85	2157
27G	107.05	15.02	7.84	944	14182	19SKC	185	114.65	8.38	85	9745
29DC	116.35	13.67	7.33	1124	15363	20SKA	185	78.06	7.62	93	7260
30GF	123.85	11.13	7.02	1922	21390	20SKB	189.5	82.45	7.43	101	8327
30D	125.35	6.78	6.96	3902	26448	42	194.55	17.10	7.7	142	2428
30B	126.35	6.03	6.61	5730	34580	43B	204.50	16.25	7.52	273	4435
31G	129.15	6.62	6.71	6907	45724	43A	205.15	41.39	7.86	112	4636

EC = electrical conductivity.

**Figure B.13. Calculated and Actual Porewater pH and Electrical Conductivity  
Values for Borehole 299-W23-19 Sediments**

Insert Figure B.13.

**Table B.9. Anion Content of Water Extracts of Borehole 299-W23-19 Sediments (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	1:1 Extracts (mg/L)							Dilution Corrected Porewater (mg/L)						
				Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Alk*	Nitrate	Nitrite	Chloride	Sulfate	Phosphate	Fluoride	Alk*
09E	32.95	9.85	1.00	1.00	0.64	<0.04	0.16	2.34	0.14	124	10	<0.39	1.6	23	1.4	6.3	1219
15A	54.50	17.13	1.00	0.76	0.77	<0.04	0.71	11.66	<0.1	96	13	<0.69	12.2	200	1.7	13.2	1647
16A	57.45	15.82	1.00	3.10	0.78	<0.04	0.91	18.33	0.10	<b>305</b>	49	<0.63	14.4	290	1.6	12.3	4830
17J	61.75	18.84	1.00	1.35	0.45	<0.04	0.37	7.14	<0.1	58	25	<0.75	7.0	135	1.9	8.5	1101
17G	63.25	11.13	1.00	5.25	0.60	<0.04	0.39	11.86	0.12	83	58	<0.45	4.3	132	1.3	6.7	921
17F	63.75	8.53	1.00	8.83	0.72	<0.04	0.60	15.77	0.19	78	75	<0.34	5.1	135	1.6	6.1	664
17FDUP	63.75	8.56	1.01	8.3	0.73	<0.08	0.5	13.67	0.18		71	<0.69	4.3	117	1.5	6.3	
17C	65.25	9.03	1.00	12.43	0.55	<0.04	0.62	17.31	0.24	65	112	<0.36	5.6	156	2.2	5.0	586
18I	67.45	5.74	1.00	19.93	0.57	<0.04	0.91	25.14	0.44	78	114	<0.23	5.2	144	2.5	3.3	447
18E	69.45	10.19	1.00	10.26	0.54	<0.04	0.66	12.66	0.30	91	105	<0.41	6.7	129	3.1	5.5	928
18C	70.45	6.56	1.00	28.02	1.02	<0.04	1.20	22.91	1.24	160	184	<0.26	7.9	150	8.1	6.7	1047
18B	70.95	6.56	1.00	27.69	1.02	<0.08	1.28	23.02	1.76		182	<0.52	8.4	151	11.5	6.7	
19H	73.25	27.70	1.00	136.83	2.43	<0.1	2.05	15.71	0.62		3790	<2.8	56.8	435	17.2	67.3	
19G	73.75	7.49	0.86	400.86	2.54	<0.1	6.73	42.45	0.74		3002	<0.7	50.4	318	5.5	19.0	
19F	74.25	7.09	1.00	431.09	2.64	<0.04	6.69	44.49	<1	131	3056	<0.28	47.4	315	<7.1	18.7	931
19D	75.25	9.61	<b>1.18</b>	<b>321.44</b>	<b>1.52</b>	<b>&lt;0.1</b>	<b>4.6</b>	<b>28.31</b>	<b>0.89</b>		<b>3088</b>	<b>&lt;1.0</b>	<b>44.2</b>	<b>272</b>	<b>8.5</b>	<b>14.6</b>	
20F	79.25	9.47	0.76	292.01	3.35	<0.1	3.87	31.17	1.19		2766	<0.9	36.7	295	11.3	31.7	
20FDUP	79.25	9.38	1.04	250.53	4.36	<0.1	3.43	25.87	1.3		2351	<0.9	32.2	243	12.2	40.9	
20E	79.75	7.79	1.00	275.95	3.78	<0.1	3.43	27.1	1.37		2150	<0.8	26.7	211	10.7	29.5	
20D	80.25	6.00	1.00	358.65	2.01	<0.04	4.63	35.21	3.16	175	2151	<0.24	27.8	211	18.9	12.1	1051
21A	86.00	13.58	0.61	73.51	3.83	<0.1	1.21	12.68	0.67		998	<1.4	16.4	172	9.1	52.0	
22D	88.10	6.07	1.00	446	2.62	<0.04	6.46	44.80	1.61	182	2716	<0.24	39.5	274	10.7	15.9	1105
24A	95.00	10.82	1.00	340.37	0.72	<0.04	4.11	37.24	1.45	215	3682	<0.43	44.5	403	15.7	7.8	2320
25B	99.06	14.17	0.81	183.64	1.71	<0.1	3.42	33.28	0.83		2603	<1.4	48.5	472	11.8	24.2	

**Table B.9. Anion Content of Water Extracts of Borehole 299-W23-19 Sediments (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	1:1 Extracts (mg/L)							Dilution Corrected Porewater (mg/L)						
				Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Alk*	Nitrate	Nitrite	Chloride	Sulfate	Phosphate	Fluoride	Alk*
25BDUP	99.06	15.85	0.97	141.66	1.83	<0.1	2.46	25.36	0.81		2245	<1.6	39.0	402	12.8	29.0	
25A	100.06	11.40	0.79	423.71	0.58	<0.1	6.94	61.74	<0.5		4831	<1.1	79.1	704	5.7	6.6	
26E	102.95	13.75	1.00	156.9	0.95	<0.1	3.16	34.49	1.28		2157	<1.4	43.4	474	17.6	13.1	
26A	104.95	12.21	1.00	75.31	1.06	<0.1	2.49	28.44	0.84		919	<1.2	30.4	347	10.3	12.9	
27G	107.05	15.02	1.00	342.38	<2	<0.04	4.71	39.20	1.07	611	5144	<0.60	70.8	589	16.1	<30	9174
29D	116.35	13.67	1.00	467.69	0.35	<0.04	5.79	45.67	ND	49	6392	<0.55	79.1	624	ND	4.8	676
30G	123.85	11.13	1.00	864.67	<0.4	0.72	9.55	83.98	1.72	84	9623	8.01	106.3	935	19.1	<4.5	936
30D	125.35	6.78	0.79	2179.7	0.82	<0.1	17.81	89.94	<5		14774	<0.7	120.7	610	<33.9	5.6	
30B	126.35	6.03	1.00	3168.8	<0.2	42.80	25.28	39.80	0.91	83	19123	258.29	152.6	240	<5.5	<1.2	502
30BDUP	126.35	6.03	1.00	3439.5	<0.2	31.17	26.88	43.8	3.49		20757	188.11	162.2	264	<21.1	<1.2	
31G	129.15	6.62	1.00	3932.5	<0.2	27.78	32.52	23.92	<1	66	26033	183.90	215.3	158	<6.6	<1.3	436
31A	132.15	6.36	1.00	3195.7	<0.5	<1	30.57	10.95	<5		20329	<6	194.5	70	<31.8	<3.2	
32D	134.25	11.80	0.84	811.76	1.16	<1	9.94	6.86	<5		9577	<12	117.3	81	<59.0	13.7	
32A	135.80	5.79	1.00	2775.7	<0.2	12.86	26.98	14.88	<1	38	16064	74.43	156.1	86	<5.8	<1.2	221
33G	137.65	6.43	1.00	2733.6	<0.2	9.34	26.41	10.33	<1	72	17588	60.09	169.9	66	<6.4	<1.3	462
33B	140.15	6.45	1.00	2738.1	<0.2	13.15	25.44	11.05	<1	34	17672	84.87	164.2	71	<6.5	<1.3	219
35K	141.05	8.72	1.00	2593.9	<0.2	8.51	23.87	8.49	<1	43	22623	74.22	208.2	74	<8.7	<1.7	376
35C	144.85	6.15	1.00	1552.5	<0.2	2.01	15.77	10.75	<1	134	9550	12.36	97.0	66	<6.2	<1.2	826
35A	145.85	3.89	1.00	2454.2	<0.2	4.16	26.28	12.40	8.12	41	9544	16.18	102.2	48	<31.6	<0.8	160
36D	147.45	10.20	1.00	761.89	0.75	<1	9.86	7.66	<5		7774	<10	100.6	78	<51.0	7.7	
36B	148.45	4.35	1.00	1385.4	<0.2	0.78	17.42	19.82	<1	39	6033	3.40	75.9	86	<4.4	<0.9	171
37D	149.65	7.72	1.00	2140	<0.2	2.32	21.31	11.87	<1	59	16524	17.91	164.5	92	<7.7	<1.5	452
38G	152.10	4.32	1.00	408.97	1.28	<1	11.33	17.88	<5		1768	<4	49.0	77	<21.6	5.5	
38E	153.10	7.11	1.00	241.57	<2	<0.04	7.39	17.71	0.22	60	1718	<0.28	52.6	126	<1.6	<14	425

**Table B.9. Anion Content of Water Extracts of Borehole 299-W23-19 Sediments (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	1:1 Extracts (mg/L)							Dilution Corrected Porewater (mg/L)						
				Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Alk*	Nitrate	Nitrite	Chloride	Sulfate	Phosphate	Fluoride	Alk*
38E-DUP	153.10	7.11	1.00	216.81	<2	<0.04	6.91	14.34	0.18		1543	<0.28	49.2	102	<1.3	<14	
39D	155.35	9.49	0.82	292.81	0.31	<0.1	7.61	14.22	<0.5		2779	<0.9	72.2	135	<4.7	2.9	
39C	155.85	12.83	1.00	90.08	0.30	<0.04	3.81	11.03	<1	76	1156	<0.51	48.9	142	<12.8	3.85	971
39C-dup	155.85	12.82	1.00	83.59	0.30	<0.04	3.59	11.25	<1		1072	<0.51	46.0	144	<12.8	12.82	
40B	157.75	20.49	1.00	3.56	0.32	<0.04	1.34	5.98	<0.1		73	<0.82	27.5	123	<2.0	6.56	
40	158.65	10.96	<b>1.38</b>	<b>24.93</b>	<b>0.56</b>	<b>&lt;0.1</b>	<b>2.12</b>	<b>38.84</b>	<b>&lt;0.5</b>	<b>74</b>	<b>273</b>	<b>&lt;1.1</b>	<b>23.2</b>	<b>426</b>	<b>&lt;5.5</b>	<b>6.1</b>	<b>815</b>
17SK	159.75	11.92	1.00	32.24	0.84	<0.1	4.25	14.47	<0.5		384	<1.2	50.7	173	<6.0	10.0	
18SKA	161	14.68	1.01	23.02	2.3	<0.1	3.03	17.31	<5		338	<1.5	44.5	254	<73.4	33.8	
18SKB	161.00	19.78	1.04	28.29	<0.1	2.72	0.94	16.99	<0.5		560	54	18.6	336	<9.9	<2.0	
18SKC	166.50	34.13	1.01	17.19	<0.1	3.75	1	12.96	<0.5		587	128	34.1	442	<17.1	<3.4	
19SKA	166.50	74.25	1.00	11.36	1.01	<0.1	1.6	10.29	<0.5		843	<7.4	118.8	764	<37.1	75.0	
19SKB	176.00	80.64	1.00	5.65	0.44	<0.1	1.27	11.28	<0.5		456	<8.1	102.4	910	<40.3	35.5	
41A	184.45	25.37	1.00	6.53	0.37	<0.04	1.28	5.17	<0.1	440	166	<1.01	32.5	131	<2.5	9.4	11170
19SKC	185	114.65	1.01	3.87	0.42	<0.1	1.36	6.5	<0.5		444	<11.5	155.9	745	<57.3	48.2	
20SKA	185	78.06	1.00	0.78	0.65	<0.1	1.45	4.13	<0.5		61	<7.8	113.2	322	<39.0	50.7	
20SKB	189.5	82.45	0.94	3.13	0.58	<0.1	2.51	5.09	<0.5		258	<8.2	206.9	420	<41.2	47.8	
42	194.55	17.10	1.00	1.14	0.65	<0.04	2.00	7.38	<0.1	57	19	<0.68	34.2	126	<1.7	11.1	966
43B	204.50	16.25	1.00	76.79	0.36	<0.04	3.59	7.68	0.13	45	1248	<0.65	58.3	125	<2.1	5.85	736
43A	205.15	41.39	1.00	25.29	0.53	<0.1	1.47	3.68	<0.5		1047	<4.1	60.8	152	<20.7	21.9	

Note: Values in *italics* represent water extracts that were inadvertently run at a ratio of less than 1:1 and analytes reported may be biased high in relationship to the correct 1:1 extract samples. Values in **bold** represent water extracts that were inadvertently run at a ratio greater than 1:1 and analytes reported may be biased low in relationship to the correct 1:1 extract samples.

\*Alk = alkalinity as mg/L of CaCO<sub>3</sub>; alkalinity values in bold red type are anomalous. Auto-Titrator was acting up.  
ND = not determined; blank cells also represent analytes not determined/measured.

**Figure B.14. Anions Calculated and Actual Porewaters  
for Borehole 299-W23-19 Sediments**

Insert Figure B.14.

Water extract cation concentrations as a function of depth are listed in Table B.10 and graphed in Figure B.15. Among the cations, elevated sodium concentrations are the primary tank SX-115 fluid indicator. Maximum values begin abruptly at 22 m (73 ft) bgs, remain elevated above 1000 mg/L until 38 m (126 ft) bgs, and gradually decrease. The lower edge of the sodium zone is blurred (approximately 43 to 46 m [143 to 150 ft] bgs). Calcium, magnesium, potassium, and natural strontium show elevated concentrations between 35 and 46 m (116 and 150 ft) bgs, a depth range slightly lower than the sodium range. The relative positioning of sodium concentration ranges versus that of the other cations supports the hypothesis that sodium preferentially replaces these cations in sorption sites as it migrates vertically and pushes them ahead to the leading edge of the plume.

A small secondary elevated sodium concentration depth interval occurs in the Ringold Formation between 51 and 58 m (166 and 190 ft) bgs, approximately the same location as the secondary elevated sulfate and chloride concentrations. Calcium, potassium, and iron are also slightly elevated, once again suggesting that residual constituents from fluids that created the high water table in the 1980s were left behind in the soil column after drainage.

The last group of constituents analyzed included radionuclides and trace metals. Of these only technetium-99 and chromium are clearly present in concentrations above background and are attributed to have originated in the tank SX-115 fluid. Water extract concentrations are listed in Table B.11, and technetium-99 distribution is shown in Figure B.16. The technetium-99 elevated concentration pattern closely mimics the nitrate concentration distribution where clearly elevated concentrations begin at 22 m (73 ft) bgs and reaches maximum concentrations of approximately 1,100 to 3,000 pCi/L between 38 and 46 m (125 and 150 ft) bgs. Another sharp drop occurs at 49 m (160 ft) bgs, at the contact between subunit PPlc and the Ringold Formation. Chromium concentration values increase above background beginning at 20 m (67 ft) bgs and reach maximum concentrations of 42,000 to 122,000 µg/L between 22 and 38 m (73 and 125 ft) bgs. The occurrence of the maximum chromium range high in the soil column relative to technetium-99 indicates some retarding chemical mechanism has slowed chromium migration relative to technetium-99. Work completed by the S&T activity (Appendix D, Section D.4.1) indicates that iron(II)-rich minerals in the vadose zone soil reduce the oxidation state of a fraction of the chromium in solution from +6 to +3. In the +3 state, chromium is removed from solution by sorption or coprecipitation in iron(II)-rich minerals.

Trace constituents of other radionuclides are present in the soil column including cesium-137, uranium, and tritium. Cesium-137 occurs at concentrations of approximately 0.1 to 0.6 pCi/g between 20 and 23 m (67 and 74 ft) bgs and may be derived from the tank SX-115 leak. If so, the depth interval marks the approximate location of initial tank fluid occurrence at this location. Uranium occurs at background level and tritium, whose concentration levels are low and occur in the Plio-Pleistocene unit, is of uncertain origin.

### **B.3.4 CONTAMINANT CONCENTRATIONS**

Contaminant concentrations at borehole 299-W23-19 were not analyzed.



**Table B.10. Calculated Porewater Cation Composition from Water Extracts from  
Vadose Zone Sediments from Borehole 299-W23-19 (4 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Aluminum (µg/L)	Barium (µg/L)	Calcium (mg/L)	Iron (µg/L)	Potassium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (µg/L)	Sulfate (mg/L)	Manganese (µg/L)
09E	32.95	9.85	1.00	<b>341</b>	248	66	335	44	12	185	189	380	19	10
15A	54.50	17.13	1.00	<b>327</b>	153	134	1097	105	27	611	277	319	226	73
16A	57.45	15.82	1.00	<b>51</b>	197	143	680	79	30	432	253	186	266	38
17J	61.75	18.84	1.00	<b>548</b>	170	101	1093	60	21	359	237	297	163	41
17G	63.25	11.13	1.00	<b>85</b>	156	71	746	32	14	250	172	142	132	21
17F	63.75	8.53	1.00	<b>211</b>	85	65	1416	25	13	243	154	135	125	32
17F-dup	64.75	8.56	1.01	<b>317</b>	101	63	592	25	12	215	159	375	105	11
17DE-aft	64.75	10.70	0.96	<b>164</b>	161	72	308	27	14	316	198	123	126	12
17DE	64.75	5.05	1.00	<b>&lt;250</b>	65	62	71	19	8	164	94	315	157	2
17C	65.25	9.03	1.00	<b>&lt;250</b>	144	77	824	29	15	231	150	123	178	22
18I	67.45	5.74	1.00	<b>2045</b>	103	62	4160	19	12	163	103	154	146	64
18E	69.45	10.19	1.00	<b>182</b>	81	36	526	26	6	373	168	205	126	16
18CB	70.70	6.56	1.00	<b>1882</b>	72	8	4559	11	1	537	119	206	134	84
18CB-dup	70.70	6.56	1.00	<b>2896</b>	90	10	7919	14	2	518	124	54	147	140
19H	73.25	27.70	1.00	<b>3057</b>	692	25	5361	39	3	<b>3081</b>	372	192	458	131
19G	73.75	7.49	<b>0.86</b>	<b>&lt;250</b>	112	18	1477	23	2	<b>1632</b>	112	130	311	54
19E	74.75	7.09	1.00	<b>442</b>	92	17	2543	21	2	<b>1542</b>	113	36	321	96
19D	75.25	9.61	<b>1.18</b>	<b>1554</b>	154	12	3340	22	1	<b>1825</b>	148	98	273	67
20F	79.25	9.47	<b>0.76</b>	<b>529</b>	332	10	1694	25	1	<b>1977</b>	148	86	301	39
20F-dup	79.25	9.38	1.04	<b>1267</b>	910	12	5357	23	1	<b>1841</b>	156	122	265	126
20E	79.75	7.79	1.00	<b>1166</b>	156	9	9829	19	1	<b>1472</b>	125	74	214	146
20D	80.25	6.00	1.00	<b>1210</b>	78	6	6094	15	1	<b>1365</b>	97	2998	219	115
21A	86.00	13.58	<b>0.61</b>	<b>2555</b>	693	10	2660	24	2	<b>2046</b>	254	106	190	76
22D	88.10	6.07	1.00	<b>490</b>	103	7	3413	18	1	<b>1476</b>	63	3033	261	85

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**Table B.10. Calculated Porewater Cation Composition from Water Extracts from  
Vadose Zone Sediments from Borehole 299-W23-19 (4 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Aluminum (µg/L)	Barium (µg/L)	Calcium (mg/L)	Iron (µg/L)	Potassium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (µg/L)	Sulfate (mg/L)	Manganese (µg/L)
24A	95.00	10.82	1.00	<b>2038</b>	141	17	3773	28	3	<b>1921</b>	103	140	378	61
25B	99.06	14.17	<b>0.81</b>	<b>747</b>	935	29	365	35	4	<b>1781</b>	148	210	468	11
25B-dup	99.06	15.85	0.97	<b>888</b>	206	19	396	31	3	<b>1612</b>	173	128	396	8
25A	100.06	11.40	<b>0.79</b>	<b>811</b>	365	103	899	62	16	<b>2351</b>	134	651	697	13
26E	102.95	13.75	1.00	<b>&lt;1000</b>	289	16	1142	26	2	<b>1589</b>	127	129	454	39
26A	104.95	12.21	1.00	<b>890</b>	281	9	448	18	1	<b>1360</b>	111	74	322	18
27G	107.05	15.02	1.00	<b>&lt;1000</b>	210	162	480	57	32	<b>2457</b>	181	509	570	12
29D	116.35	13.67	1.00	<b>374</b>	<b>670</b>	<b>844</b>	107	<b>128</b>	<b>158</b>	<b>1619</b>	191	<b>4116</b>	511	52
30G	123.85	11.13	1.00	<b>&lt;500</b>	<b>1157</b>	<b>1670</b>	23	<b>170</b>	<b>338</b>	<b>1481</b>	122	<b>8332</b>	798	428
30D	125.35	6.78	<b>0.79</b>	<b>&lt;500</b>	<b>705</b>	<b>2653</b>	30	<b>142</b>	<b>518</b>	<b>1111</b>	74	<b>12930</b>	587	296
30B	126.35	6.03	1.00	<b>&lt;500</b>	<b>1575</b>	3906	1773	<b>112</b>	<b>749</b>	<b>1289</b>	67	<b>20317</b>	249	818
30B-dup	126.35	6.03	1.00	<b>&lt;500</b>	<b>1730</b>	<b>4349</b>	48	<b>122</b>	<b>835</b>	<b>1414</b>	71	<b>23461</b>	268	832
31G-1st	129.15	6.62	1.00	<b>&lt;500</b>	<b>7202</b>	<b>5618</b>	<b>&lt;50</b>	<b>129</b>	<b>1150</b>	<b>818</b>	71	<b>35522</b>	93	883
<b>31G</b>	129.15	5.15	1.00	<b>&lt;500</b>	<b>7549</b>	<b>5000</b>	12	<b>142</b>	<b>999</b>	<b>680</b>	51	<b>30836</b>	82	728
31A	132.15	6.36	1.00	<b>&lt;500</b>	<b>6285</b>	<b>3740</b>	63	<b>147</b>	<b>892</b>	<b>655</b>	71	<b>23715</b>	71	335
<b>31A</b>	132.15	6.35	1.00	<b>&lt;500</b>	<b>5493</b>	<b>3522</b>	28	<b>132</b>	<b>819</b>	<b>589</b>	66	<b>22157</b>	55	301
32D	134.25	11.80	<b>0.84</b>	<b>&lt;500</b>	<b>2560</b>	<b>1788</b>	88	<b>128</b>	<b>472</b>	<b>513</b>	127	<b>9996</b>	77	70
32A	135.80	5.79	1.00	<b>&lt;500</b>	<b>5168</b>	<b>3374</b>	1	<b>100</b>	<b>823</b>	<b>534</b>	60	<b>19626</b>	69	250
33G	137.65	6.43	1.00	<b>&lt;500</b>	<b>5044</b>	<b>3578</b>	<b>&lt;50</b>	<b>104</b>	<b>893</b>	<b>523</b>	64	<b>20064</b>	65	306
33B	140.15	6.45	1.00	<b>&lt;500</b>	<b>5486</b>	<b>3498</b>	6	<b>111</b>	<b>876</b>	<b>528</b>	65	<b>21405</b>	75	253
35K	"141.05"	8.72	1.00	<b>&lt;500</b>	<b>7003</b>	<b>4552</b>	35	<b>139</b>	<b>1191</b>	<b>689</b>	88	<b>26880</b>	84	450
35IH-aft	141.85	6.30	1.00	<b>&lt;500</b>	<b>4275</b>	<b>2885</b>	151	<b>89</b>	<b>817</b>	<b>533</b>	64	<b>17040</b>	73	30
35F-aft	143.35	7.18	1.04	<b>&lt;500</b>	<b>3275</b>	<b>2361</b>	151	<b>82</b>	<b>723</b>	<b>478</b>	74	<b>13667</b>	87	28
35C	144.85	6.15	1.00	<b>&lt;500</b>	<b>2805</b>	<b>1743</b>	18	<b>81</b>	<b>521</b>	391	55	<b>9738</b>	73	134

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**Table B.10. Calculated Porewater Cation Composition from Water Extracts from  
Vadose Zone Sediments from Borehole 299-W23-19 (4 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Aluminum (µg/L)	Barium (µg/L)	Calcium (mg/L)	Iron (µg/L)	Potassium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (µg/L)	Sulfate (mg/L)	Manganese (µg/L)
35A	145.85	3.89	1.00	<500	2921	1811	16	57	554	412	43	10833	55	9
36D	147.45	10.20	1.00	<500	2959	1388	81	106	476	430	85	8160	76	29
36B	148.45	4.35	1.00	<500	1859	1047	30	56	377	341	47	6238	71	6
37D	149.65	7.72	1.00	<500	5891	3086	<50	150	873	554	74	17468	95	2496
38G	152.10	4.32	1.00	<500	661	282	25	36	122	192	48	1753	80	2
38G	152.10	4.32	1.00	<500	709	300	55	37	129	175	47	1845	76	3
38E	153.10	7.11	1.00	93	783	268	138	49	124	257	70	1472	100	8
38E-dup	153.10	7.11	1.00	162	665	252	25	53	117	237	72	1454	95	27
38A-aft	155.10	10.92	1.00	<500	448	152	680	50	74	242	162	513	151	30
39D	155.35	9.49	0.82	<500	2743	526	97	91	226	352	111	3365	179	66
39C	155.85	12.83	1.00	151	706	250	285	75	122	318	222	1231	139	9
39C-dup	155.85	12.82	1.00	<500	554	237	<50	66	115	309	206	1088	131	12
40B	157.75	20.49	1.00	156	451	218	746	79	104	328	323	1210	126	30
40	158.65	10.96	1.38	<500	932	210	65	66	92	226	189	1268	471	6
17SK	159.75	11.92	1.00	<500	596	170	89	65	67	273	195	1083	188	45
18SKA	161	14.68	1.01	<500	822	180	46	74	66	317	222	1088	267	45
18SKB	161.00	19.78	1.04	<500	1009	235	170	97	90	392	278	1371	368	62
18SKC	166.50	34.13	1.01	<500	1843	157	222	118	42	483	239	1018	480	22
19SKA	166.50	74.25	1.00	<500	1336	343	379	209	62	857	626	2036	821	29
19SKB	176.00	80.64	1.00	<500	887	372	419	223	56	904	814	1870	878	79
41A	184.45	25.37	1.00	297	127	76	1091	55	24	213	274	845	128	37
19SKC	185	114.65	1.01	<500	1605	315	757	235	87	965	951	1873	796	83
20SKA	185	78.06	1.00	<500	1952	294	1226	211	74	776	606	1558	342	310
20SKB	189.5	82.45	0.94	<500	1154	308	618	223	83	877	700	1772	501	379

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**Table B.10. Calculated Porewater Cation Composition from Water Extracts from Vadose Zone Sediments from Borehole 299-W23-19 (4 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Aluminum (µg/L)	Barium (µg/L)	Calcium (mg/L)	Iron (µg/L)	Potassium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (µg/L)	Sulfate (mg/L)	Manganese (µg/L)
42	194.55	17.10	1.00	15095	257	109	15152	61	39	250	245	990	144	394
43B	204.50	16.25	1.00	421	487	280	487	72	91	267	156	1268	120	123
43A	205.15	41.39	1.00	<500	2691	173	435	101	30	411	421	1064	214	28

Notes: Extracts with incorrect water to sediment ratios are in **bold**. Note that some analytes are reported as µg/L and others mg/L.

aft = water extract AFTER Ultracentrifugation to remove actual porewater.

dup = a duplicate water extract on a separate aliquot of sediment.

SK# = sediment from air rotary sock not from core barrel.

**Figure B.15. Cations Calculated and Actual Porewaters  
for Borehole 299-W23-19 Sediments**

Insert Figure B.15.

**Table B.11. Calculated Porewater Trace Metal Composition for Water  
Extracts of Sediments from Borehole 299-W23-19 (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Technetium-99 (pCi/mL)	U	Cr	As	Se	Mo	Ag	Cd	Pb
					(µg/L)							
09E	32.95	9.85	1.00	<8	11.7	<25	244	<25	87	<1	<1.0	7.4
15A	54.50	17.13	1.00	<15	19.4	<9	131	<43	149	<4	<4.3	<286
16A	57.45	15.82	1.00	<13	15.7	<8	162	<40	191	<4	<4.0	39.6
17J	61.75	18.84	1.00	<16	20.2	9.6	248	<47	93	<5	<4.7	244.8
17G	63.25	11.13	1.00	<9	14.2	<6	213	<28	62	<3	<2.8	<28
17F	63.75	8.53	1.00	<7	12.9	12.2	185	<21	45	<2	<2.1	<21
17F-dup	64.75	8.56	1.01	<7	13.2	<4	187	<21	44	<2	<2.1	<21
17DE	64.75	5.05	1.00	<2	5.5	8.1	103	6.3	60	<1	<0.2	0.8
17DE-aft	64.75	10.70	0.96	<9	12.4	5.3	327	<27	91	<3	<2.7	<26.75
17C	65.25	9.03	1.00	<8	9.5	<4.5	185	<23	115	<2	<36.1	<23
18I	67.45	5.74	1.00	<5	5.6	96	135	<14	49	<1	<1.4	19.7
18E	69.45	10.19	1.00	<9	9.0	308	190	<25	147	<1	<1.0	6.9
18C	70.45	6.56	1.00	<6	15.6	3224	273	<16	152	0.9	<0.7	6.3
18B	70.95	6.56	1.00	<6	15.6	3343	268	<16	154	1.0	3.9	8.4
19H	73.25	27.70	1.00	357.0	55.1	43262	1175	34	1352	7.5	2.2	15.2
19G	73.75	7.49	0.86	312.4	23.1	37442	681	34	1179	7.1	1.8	12.1
19E	74.75	7.09	1.00	333.9	23.6	48547	617	22	1028	6.1	1.0	8.1
19D	75.25	9.61	1.18	317.7	32.7	30391	2266	26	656	3.9	1.4	7.2
20F	79.25	9.47	0.76	284.4	45.4	35668	2630	26	1412	4.0	2.0	7.1
20F-dup	79.25	9.38	1.04	245.8	41.2	29695	2345	18	1090	3.4	1.6	16.6
20E	79.75	7.79	1.00	198.2	20.7	21235	3463	22	667	4.1	1.4	34.8
20D	80.25	6.00	1.00	192.4	15.6	19834	2433	20	523	1.5	1.5	15.0
21A	86.00	13.58	0.61	94.4	62.3	5422	2229	20	310	1.0	0.8	4.1
22D	88.10	6.07	1.00	288.9	51.6	39232	616	17	731	3.7	0.8	10.0
24A	95.00	10.82	1.00	330.9	26.0	40792	1063	24	3850	4.4	2.7	17.0
25B	99.06	14.17	0.81	120.2	19.7	27723	868	27	164	0.4	0.9	6.2
25B-dup	99.06	15.85	0.97	122.3	20.7	28227	1099	18	144	0.5	0.6	2.3
25A	100.06	11.40	0.79	394.5	13.1	85566	466	45	273	2.3	0.8	9.6
26E	102.95	13.75	1.00	177.2	36.3	35900	1146	18	3495	1.0	4.3	9.1
26A	104.95	12.21	1.00	155.3	33.2	16064	801	18	3288	0.0	3.7	3.9
27G	107.05	15.02	1.00	545.7	14.7	122342	291	38	1875	3.8	3.8	37.6

**Table B.11. Calculated Porewater Trace Metal Composition for Water  
Extracts of Sediments from Borehole 299-W23-19 (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Technetium-99 (pCi/mL)	U	Cr	As	Se	Mo	Ag	Cd	Pb
					(µg/L)							
29D	116.35	13.67	1.00	506.2	14.1	93333	70	50	137	3.4	3.4	34.2
30G	123.85	11.13	1.00	919.4	23.8	81170	33	73	332	0.6	1.3	2.5
30D	125.35	6.78	0.79	1504.7	6.6	42511	34	123	129	2.0	0.9	2.2
30B	126.35	6.03	1.00	2034.1	6.5	1788	7.1	139	108	4.0	1.5	28.2
30B-dup	126.35	6.03	1.00	2344.4	7.1	2584	6.5	144	101	4.2	1.5	15.1
31G	129.15	6.62	1.00	3291.0	9.1	18	4.6	102	81	2.0	1.1	4.1
31G	129.15	5.15	1.00	3033.6	3.3	31	20	73	57	1.1	0.7	1.9
31A	132.15	6.36	1.00	2498.7	4.0	0.01	15	45	50	1.4	0.8	1.1
31A	132.15	6.35	1.00	2457.2	4.2	6.4	15	43	49	1.3	0.7	3.4
32D	134.25	11.80	0.84	1169.5	6.7	4.7	33	40	134	0.0	0.5	2.0
32A	135.80	5.79	1.00	2109.7	8.2	<14	2.9	68	67	1.9	0.7	<3
33G	137.65	6.43	1.00	2235.4	8.2	<16	<3	78	71	1.6	1.0	<3
33B	140.15	6.45	1.00	2117.2	10.3	<16	<3	79	104	2.3	0.9	<3
35K	"141.05"	8.72	1.00	2204.1	18.5	<22	5.0	84	164	1.4	1.2	<4
35IH-aft	141.85	6.30	1.00	1772.9	9.4	6.6	5.4	72	91	1.6	<1.6	<16
35F-aft	143.35	7.18	1.04	1613.3	10.5	5.9	6.5	49	100	<2	<1.8	<18
35C	144.85	6.15	1.00	1138.1	7.0	<15	6.5	28	121	<1	<0.6	<3
35A	145.85	3.89	1.00	1115.8	6.7	3.7	4.1	29	48	<1	<1.0	<10
36D	147.45	10.20	1.00	1170.7	7.4	3.6	18	23	141	<1	0.6	3.4
36B	148.45	4.35	1.00	831.2	8.4	6.5	5.8	22	74	<1	<1.1	<11
37D	149.65	7.72	1.00	1438.3	25.3	<19	4.0	50	208	<1	<2.1	<4
38G	152.10	4.32	1.00	237.3	7.6	4.3	19	18	83	<0	0.2	0.8
38G	152.10	4.32	1.00	249.6	7.7	3.8	20	18	88	<0	0.2	0.6
38E	153.10	7.11	1.00	152.8	12.2	5.2	43	24	147	<2	<1.8	<18
38E-dup	153.10	7.11	1.00	142.8	12.0	4.4	44	20	156	<2	<1.8	<18
38A-aft	155.10	10.92	1.00	37.3	20.1	<5	391	<27	157	<3	<2.7	<27
39D	155.35	9.49	0.82	293.2	36.1	9.9	28	21	309	<1	0.8	12
39C	155.85	12.83	1.00	138.6	36.1	<32	510	<32	160	<1	<1.3	<6
39c-dup	155.85	12.82	1.00	133.0	42.5	<32	483	<32	165	<1	<1.3	<6
40B	157.75	20.49	1.00	23.3	99.1	10.4	448	<51	220	<5	<5.1	51.2
40	158.65	10.96	1.38	29.4	217.4	11.2	194	32	445	<1	0.9	2.9

**Table B.11. Calculated Porewater Trace Metal Composition for Water  
Extracts of Sediments from Borehole 299-W23-19 (3 Sheets)**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Technetium-99 (pCi/mL)	U	Cr	As	Se	Mo	Ag	Cd	Pb
					(µg/L)							
17SK	159.75	11.92	1.00	30.7	25.3	64.6	276	30	886	<1	1.3	1.4
18SKA	161	14.68	1.01	23.6	20.0	42.9	332	27	1276	<1	2.1	8.4
18SKB	161.00	19.78	1.04	52.3	28.7	83.4	388	34	1417	<2	2.5	2.4
18SKC	166.50	34.13	1.01	53.8	3.5	41.8	12	24	1157	<3	2.1	6.3
19SKA	166.50	74.25	1.00	68.0	8.9	44.5	40	52	1547	<7	3.9	9.4
19SKB	176.00	80.64	1.00	45.1	11.6	19.0	115	54	1524	<8	4.0	26.1
41A	184.45	25.37	1.00	13.1	9.5	14.1	94	<63	384	<6	<6.3	<63
19SKC	185	114.65	1.01	31.1	12.6	<115	145	83	2368	<11	4.6	8.7
20SKA	185	78.06	1.00	14.6	19.8	0.0	191	47	1212	<8	4.2	33.7
20SKB	189.5	82.45	0.94	25.2	12.2	12.9	205	89	1887	<8	4.0	13.9
42	194.55	17.10	1.00	5.6	34.2	9.2	50	42	279	<4	<4.3	<43
43B	204.50	16.25	1.00	51.1	25.0	<8	23	<41	247	<4	<4.1	47.4
43A	205.15	41.39	1.00	176.2	9.5	23.7	217	25	576	0.2	2.2	6.9



**Figure B.16. Trace Metals Calculated from Sediment Water Extracts  
and Actual Porewaters for 299-W23-19 Sediment**

Insert Figure B.16.

### B.3.5 CHEMICAL INTERACTIONS

No specific experiments were completed on soils from this borehole to quantify geochemical reactions influencing contaminant migration. Dominant chemical reactions affecting radionuclides and tank fluid chemicals are inferred from the relative location of these constituents in the soil column, comparison of acid-leachable versus water-leachable concentrations for specific contaminants, and general knowledge of the tank fluid chemistry. Greater contaminant mobility is inferred from the occurrence of high concentration zones deeper in the vadose zone and smaller differences in concentrations leached by water versus acid.

Generally speaking, the data suggest that tank SX-115 fluid chemistry, other than providing increased amounts of certain constituents to the soil column, had little effect on the chemical behavior of contaminants in the sense that chemical reactions between tank fluid constituents and the soil column environment were largely controlled by soil-soil water reactions. Constituent anions (e.g., nitrate and technetium-99) have migrated the most rapidly and mark the leading edge of vertical tank fluid migration at this location. Chromium was slightly retarded relative to technetium-99 and nitrate, presumably because of oxidation reduction, allowing fixation on soil. Constituent cations have migrated varying distances depending on the strength of retardation mechanisms. Cesium-137 sorbed very strongly as soon as tank fluid entered the soil column. Sodium concentrations, being relatively high, successfully completed for sorption sites in vadose zone soils, were somewhat retarded. Calcium, magnesium, and indigenous strontium were displaced by sodium and pushed ahead of sodium during migration.

### B.3.6 GROUNDWATER MEASUREMENTS

Groundwater contaminants in this borehole are characterized by the largest technetium-99 concentrations currently seen in the monitoring network. Recent analyses are listed in Appendix C, Table C.17. Also, nitrate and chromium concentrations are high. The technetium-99/nitrate ratios (0.11 pCi/μg) are similar to those postulated for tank fluids. This observation, coupled with the location of borehole 299-W23-19 strongly indicates the tank SX-115 leak as the source of this groundwater contamination.

#### B.4.0 TANK SX-108 SLANT BOREHOLE

This section summarizes data reported in *Geologic and Geochemical Data Collected from Vadose Zone Sediments from Slant Borehole [SX-108] in the S/SX Waste Management Area and Preliminary Interpretations* (Serne et al. 2001d) except for the groundwater sample data, which are reported in the WMA S-SX RCRA groundwater monitoring report (Johnson and Chou 2000). The SX-108 slant borehole was completed to further characterize the nature and extent of vadose zone contaminants supplied by a tank SX-108 leak. This borehole was drilled specifically to sample soils as close the tank leak site as possible and to investigate tank fluid migration underneath the tank, an area which has received no evaluation other than gross gamma measurements along laterals in the 1970s. Soils analyses from the slant borehole combined with analyses from borehole 41-09-39 provides a means of comparing tank fluid migration in two different locations with somewhat different conditions occurring. In addition to being closer to the tank leak, the slant borehole goes through the 'umbrella' region under the tank where little if any natural infiltration is anticipated, compared to the region between the tanks. Also, the addition of second borehole data provides a better idea of the three-dimensional aspect of the migrating leak distribution.

The most significant data provided by this characterization effort were soil measurements of radionuclides and chemicals attributed to this leak. Elevated concentrations of several constituents were measured in soils throughout the length of the slant borehole from 17 and 41 m (55 and 135 ft) bgs. This depth interval includes subunits H1 and H2 of the Hanford formation and part of subunit PPlz) of the Plio-Pleistocene unit. The primary radionuclides present in this zone are cesium-137 and technetium-99. Maximum cesium-137 concentrations are present between 17 and 27 m (55 and 88 ft) bgs in subunit H1 and the top part of subunit H2. Maximum technetium-99 concentrations are present in the bottom part subunit H2 and the top part of subunit PPlz between 26 and 42 m (85 and 138 ft) bgs. The primary chemical characteristics attributed to tank fluid-soil interaction within this zone are elevated: pH, sodium, chromium, and nitrate. The depth of maximum technetium-99 concentration coincides with high nitrate concentrations and marks the leading edge of vertical tank fluid migration at this location. Also, this is the only borehole in which iodine-129 has been detected. Iodine-129 occurs between 24 and 40 m (80 and 130 ft) bgs at about 18,000 to 43,000 pCi/L.

It is of note that most constituents show more than one peak concentration with depth within their respective highest concentration ranges. Several mechanisms may have played a role in creating these patterns of contaminant concentration, including stratigraphic heterogeneities that encourage layering, thermal cycling effects that temporarily created circulating fluids in the soil column, and/or multiple leaks. None of these various options are clearly preferred.

Moisture content measurements are somewhat dry and in situ temperatures are elevated relative to undisturbed Hanford formation soils. Both conditions plus the presence of the tank suggest that relatively little drainage is occurring in this area. The lack of tank fluid contaminants below the Plio-Pleistocene unit and the low concentrations of technetium-99 and nitrate in groundwater samples from nearby borehole 41-09-39 indicate that contaminants from this area have not reached the unconfined aquifer at this location.

## B.4.1 GEOLOGY

The SX-108 slant borehole intersected three primary stratigraphic units: (1) backfill, which was not sampled, (2) the Hanford formation, and (3) the top of the Plio-Pleistocene unit. The backfill appears to extend to about 16.2 m (53 ft) bgs where it contacts the Hanford formation. The next 2.6 m (8 ft) bgs is interpreted to correlate with the upper fine sand and mud sequence of the Hanford formation subunit H1a. Below this lies the 4.2 m (14 ft) thick middle coarse sand and gravel sequence of subunit H1. The contact between the Hanford formation and the Plio-Pleistocene unit is interpreted to occur at 38.5 m (126 ft) bgs. The frequency and manner in which the samples were taken limits the completeness of the geologic description that can be made.

### B.4.1.1 Backfill

The backfill was not sampled. The contact depth of the backfill with the Hanford formation at 16.2 m (53.1 ft) bgs is supported by tank farm engineering drawings (H-2-37985 sheet 2 of 2), an increase in blow counts required to advance the casing, and an increase in apparent moisture content as indicated in the neutron moisture log.

### B.4.1.2 Hanford formation

All three Hanford formation subunits (H1a, H1, and H2) were present at the SX-108 slant borehole and sampled.

- **Subunit H1a** – This subunit, the upper fine sand and mud sequence, is believed to be approximately 2.6 m (8.4 ft) thick extending from the base of the backfill to a vertical depth of approximately 18.7 m (61.5 ft) bgs. The location of this contact is supported by a slight increase in the blow counts and a sharp decrease in the neutron-neutron moisture log response. Layering was evident in the single sample retrieved from subunit H1a. From 16.6 to 16.9 m (54.5 to 55.3 ft) bgs the sample exhibited a layer of dry gray muddy (silty) sand containing some possible rock flour, overlying a moist muddy, medium sand.
- **Subunit H1** – This subunit, the middle coarse sand and gravel sequence, is estimated to be approximately 4.2 m (13.8 ft) thick extending to a vertical depth of approximately 22.9 m (75.3 ft) bgs. The depth to this contact is supported by a sharp decrease in blow counts and an increase in the neutron-neutron moisture log response. The moisture log response is further substantiated by an increase in gravimetric moisture content below the contact. Two samples were recovered from subunit H1. One sample was lost. The recovered samples show some coarse layering. Sample S0070-03 was described as a dry grayish-brown medium to fine sand with some mud and gravel fragments (up to medium pebble). Sample S0070-04 contained some fine gray powder (rock flour) and the remainder of the sample was a salt and pepper textured medium to fine sand; no gravel was noted.
- **Subunit H2** – This subunit, the lower fine sand and mud sequence, is estimated to be about 15.6 m (51.1 ft) thick, extending to a vertical depth of approximately 38.5 m (126.4 ft) bgs. This depth is supported by a slight increase in the blow counts and a sharp increase in the neutron-neutron moisture log response. There is a parallel increase in

gravimetric moisture content of the samples below the contact. Ten split-spoon samples were collected through this horizon between 22.9 and 38.5 m (75.3 to 126.4 ft) bgs. Subunit H2 is composed of stratified sand, muddy sand and mud. The laminar nature of this unit is one of its outstanding characteristics. Thin laminations of mud and sand commonly separate the sand strata.

#### **B.4.1.3 Plio-Pleistocene Unit**

The Plio-Pleistocene unit was penetrated but its lower contact was not encountered in the slant borehole. Three split-spoon samples were collected from this horizon. The unit is composed of interstratified mud and muddy, very fine sand with occasional very fine sand strata (i.e., PPlz subunit). The sandier strata were described as friable and frequently exhibiting finely laminated muds.

### **B.4.2 GEOPHYSICAL AND PHYSICAL PROPERTY MEASUREMENTS**

Several geophysical logging techniques were used during and after installation of the SX-108 slant borehole. These techniques included the following:

- Gyroscopic borehole surveys
- Casing wall temperature logging using an infrared sensor
- Neutron-neutron moisture logging
- High-purity germanium spectral gamma logging
- High-rate gamma logging.

A composite of the temperature, moisture, spectral gamma, and high-rate gamma logs (Gardner and Reynolds 2000) is shown in Figure B.17.

The neutron-neutron moisture log recorded the average volumetric moisture content within a 20 to 30 cm (8 to 12 in.) radius. A slightly increased moisture content was noted between vertical depths of 15 and 18 m (50 and 60 ft) bgs, and second significant moisture content change noted at 33 m (107 ft) bgs. These moisture content changes correlate well with changes in the geologic materials.

Several spectral-gamma and high-rate gamma logging events were conducted using different logging systems, shielding configurations, and counting times. Cesium-137 was the only gamma-emitting contaminant detected. Above 16 m (52 ft) bgs, cesium-137 concentrations were generally less than 20 pCi/g, and were attributed (most likely) to internal casing contamination (Gardner and Reynolds 2000). This internal casing contamination resulted from the loss of sample S0070-02 down the borehole. Between depths of 16 and 27 m (53 and 90 ft) bgs very high concentrations of cesium-137 (on the order of  $10^8$  pCi/g) were measured. Internal contamination and/or dragdown most likely dominate contamination detected below 27 m (90 ft) bgs (Gardner and Reynolds 2000).

**Figure B.17. Geophysics Logging Graph for SX-108 Slant Borehole**

Insert Figure B.17.

Laboratory measurements of soil moisture content (Table B.12 and Figure B.18) show similar trends in relative concentrations as the neutron-neutron moisture measurements. The moisture profile shows one high peak in subunit H2 at a laminated sand facies with a silt tringer at 32 m (105 ft) bgs. With the exception of one sample, the Plio-Pleistocene unit soils show generally the highest moisture content in the soil column.

### **B.4.3 SOIL WATER CHEMISTRY MEASUREMENTS**

In addition to soil physical property measurements (Section B.4.2), an extensive water chemistry analysis has been completed for samples collected at the SX-108 slant borehole between 17 and 44 m (55 and 145 ft) bgs. The primary means of measuring porewater composition was to add deionized water to soil samples to generate enough water for performing analyses. By back-calculating for the dilution introduced by the added water, 'true' concentrations were derived. For a few samples porewater was directly separated from the same soil sample or one nearby and analyzed directly. By comparing the dilution-corrected water extract data with the porewater data in these few samples, an indication of the closeness of the water extract chemistry to original water chemistry was determined. In general, comparisons were not exact but concentration values were generally within a factor of two or better, agreement improved with increasing constituent concentration, and both sets of data showed similar concentrations versus soil depth correlations. Thus, the water extract method is an effective tool for evaluating tank fluid interactions with vadose zone soil.

Water extract pH and electrical conductivity measurements with depth are listed in Table B.13 and graphed in Figure B.19. Elevated pH values (greater than 9.) are measured between 17 and 25 m (55 and 85 ft) bgs primarily in subunits H1a and H1 and the top part of subunit H2. Because pH values are expected to decrease as increasing interaction with soil and soil water occurs, the location of maximum pH values suggests the approximate initial depth of tank fluid interaction with the vadose zone at this location. As with most chemical indicators at this borehole in the zones of elevated value, an apparent bimodal distribution of pH values is created by the low pH value (8) measured in the middle of the elevated zone at 25 m (80.6 ft) bgs. Increases in electrical conductivity values compared to undisturbed soil water values are also an indicator of tank fluid occurrence in soil. Maximum values of approximately 100,000 to 133,000  $\mu\text{S}/\text{cm}$  are measured between 26 and 30 m (85 and 97 ft) bgs. A secondary range of elevated electrical conductivity values occurs between 35 and 40 m (114 and 130 ft) bgs, primarily at the bottom of subunit H2 and the top of the Plio-Pleistocene subunit PPlz. Maximum electrical conductivity values are an indicator of location for mobile tank fluid constituents and maximum vertical penetration of tank fluids.

**Table B.12. Moisture Content (wt%)  
SX-108 Slant Borehole Sediments**

<b>Lithologic Unit</b>	<b>Sample ID</b>	<b>Vertical Depth (ft bgs)</b>	<b>Moisture (%)</b>
H1A	01B	54.5-54.9	ND
H1A	01A	54.9-55.3	4.33
H1	02B	63.0-63.5	NS
H1	02A	63.5-63.7	NS
H1	03B	67.3-67.7	3.76
H1	03A	67.7-68.1	2.76
H1	04B	71.5-71.9	3.55
H1	04A	71.9-72.4	2.77
H2	05B	75.7-76.2	6.48
H2	05A	76.2-76.6	4.69
H2	06B	79.9-80.4	3.50
H2	06A	80.4-80.8	3.68
H2	07B	84.1-84.6	6.60
H2	07A	84.6-85.0	6.18
H2	08B	88.3-88.8	4.52
H2	08A	88.8-89.2	6.02
H2	09B	92.5-92.9	5.32
H2	09A	92.9-93.3	2.35
H2	10B	96.6-97.1	4.62
H2	10A	97.1-97.5	1.91
H2	11B	101.0-101.5	5.50
H2	11A	101.5-101.9	3.15
H2	12B	104.9-105.4	7.02
H2	12A	105.4-105.8	21.35
H2	13B	113.1-113.6	7.95
H2	13A	113.6-114.0	7.64
PPlz	14B	121.3-121.7	8.51
PPlz	14A	121.7-122.2	11.95
PPlz	15B	129.4-129.9	17.50
PPlz	15A	129.9-130.3	17.42
PPlz	16B	137.5-138.0	15.13
PPlz	16A	138.0-138.4	7.50
PPlz	17B	144.0-144.4	14.49
PPlz	17A	144.4-144.9	19.70

ND = not determined.

NS = no sample.



**Figure B.18. Moisture Content (wt%) in Vadose Zone  
Sediment Profile at SX-108 Slant Borehole**

Insert Figure B.18.

**Table B.13. Water Extract pH and Electrical Conductivity Values at SX-108 Slant Borehole**

Sample ID	Vertical Depth (ft bgs)	Dilution Factor	1:1 pH	1:1 EC (mS/cm)	Pore EC (mS/cm)
01A	55.1	23.13	9.16	0.404	9.34
02A	63.02	NS	NS	NS	NS
03AB	67.9	36.88	9.58	0.701	25.85
04A	72.2	36.15	9.54	0.576	9.57
05A	76.4	21.36	9.78	0.877	14.21
06A	80.6	27.18	8.00	16.71	454.2
07A	84.8	16.20	9.55	54.62	1166.5
08A	89.0	16.61	7.83	49.01	1771.6
09A	93.1	42.56	7.88	31.76	1009.3
10A	97.3	52.34	8.23	25.56	1337.7
11A	101.7	31.78	8.38	13.93	592.8
12A	105.6	4.69	8.02	2.36	11.04
13A	113.8	13.38	7.99	29.78	398.4
14A	122.0	8.69	7.82	30.24	262.8
15A	130.1	5.74	7.45	40.01	229.7
16A	138.2	13.31	7.24	5.80	77.16
17A	144.6	5.08	7.22	3.47	17.63

EC = electrical conductivity.  
NS = no sample was available.

**Figure B.19. SX-108 Slant Borehole pH and  
Electrical Conductivity Profiles with Depth**

Insert Figure B.19.

Water extract anion concentrations as a function of depth are listed in Table B.14. Nitrate, chloride, and sulfate concentrations with depth are shown in Figure B.20. The primary indicator of tank fluid occurrence is elevated nitrate concentrations, which are measured through the borehole with maximum values between 180,000 and 995,000 mg/L between 25 and 39 m (81 and 130 ft) bgs. An apparent bimodal distribution of nitrate values is created by the low nitrate value (7,191 mg/L) measured in the middle of the elevated zone at 32 m (105.6 ft) bgs. It is probable that the bottom of the nitrate range was not reached in this sampling effort. Elevated levels of chloride (between 26 and 44 m [85 and 145 ft]) and sulfate (between 20 and 39 m [65 and 127 ft]) are also observed. Chloride maximum concentrations (between 27 and 30 m [89 and 130 ft] bgs) and sulfate maximum concentrations between 25 and 40 m (81 and 130 ft) bgs track closely with nitrate in subunit H2 and subunit PPlz. The minimum chlorine and sulfate concentrations (109 and 147 mg/L, respectively) at 32 m (105.6 ft) bgs establishes an apparent bimodal distribution for both anions. Overall, the anion concentrations appear to be diminishing rapidly in the deepest sample and indicate the leading edge of the tank fluid migration near the bottom of the borehole (44 m [145 ft]).

Water extract cation concentrations as a function of depth are listed in Table B.15 and graphed in Figure B.21. Among the cations, elevated sodium concentrations are the primary tank fluid indicator and occur throughout the SX-108 slant borehole. Maximum values begin abruptly at 25 m (81 ft) bgs, remain elevated above 65,000 mg/L through 40 m (130 ft) bgs except at 32 m (105.6 ft) bgs where sodium concentration drops to 691 mg/L. The potassium concentration distribution with depth mimics sodium. Calcium, magnesium, barium, and natural strontium show depleted concentrations above the high sodium depth range at 17 to about 27 m (55 to 90 ft) bgs and elevated concentrations between 27 and 44 m (90 and 145 ft) bgs, a depth range slightly ahead of the high sodium range. The relative positioning of sodium and perhaps potassium concentration ranges versus that of the other cations supports the hypothesis that sodium and potassium preferentially replace these cations in sorption sites as they migrate vertically and push them ahead to the leading edge of the plume.

The last group of constituents analyzed included radionuclides and trace metals. Of these, cesium-137, technetium-99, and chromium are clearly present in concentrations above background and are attributed to have originated in the tank fluid. Gamma log concentrations of cesium-137 are listed in Table B.16 and distribution is shown in Figure B.22.

Above background cesium-137 concentrations are measured throughout the borehole. The primary contamination zone is in subunit H1 and the upper half of subunit H2 between 21 and 27 m (68 and 90 ft) bgs. In this zone two peaks occur at 21 and 24 to 26 m (68 and 80 to 85 ft) bgs at concentration levels of  $2 \times 10^7$  and  $9 \times 10^7$  pCi/g. Overall, the vast majority of cesium-137 mass resides in the upper half of subunit H2 between 24 and 26 m (80 and 85 ft) bgs. Just below these peaks, cesium-137 concentrations drop by orders of magnitude (less than 1000 pCi/g at 28 m [93 ft] bgs and below).

**Table B.14. Anion Content of Water Extracts of SX-108 Slant Borehole Sediment**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	1:1 Extracts (mg/L)							Dilution Corrected Porewater (mg/L)						
				Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Alk*	Nitrate	Nitrite	Chloride	Sulfate	Phosphate	Fluoride	Alk*
1A	55.1	23.13	1.00	6.95	1.94	<0.1	1.76	20.0	<0.5	211	161	<2.31	40.7	462	<11.6	44.7	4884
1A-Dup	55.1	23.13	1.00	6.07	1.71	<0.1	1.27	17.5	<0.5	519	140	<2.31	29.4	405	<11.6	39.6	12007
3AB	67.9	36.88	1.02	29.1	3.69	0.36	3.38	21.7	0.87	382	1072	13.1	125	801	0.88	136	14105
4A	72.2	36.15	1.00	23.5	2.27	0.31	1.51	11.5	0.68	387	851	11.2	54.7	415	0.68	81.9	13977
5A	76.4	21.36	1.00	92.9	3.24	0.34	3.92	27.3	1.06	407	1984	7.30	83.8	584	1.06	69.3	8701
6A	80.6	27.18	1.00	11743	ND	ND	<10	70.9	<5	587	319225	ND	<272	1926	<136	ND	15945
7A	84.8	16.20	1.00	46645	<10	ND	26.0	607	<50	1702	755649	ND	421	9833	<810	<162	27577
8A	89.0	16.61	1.00	39713	<10	87.5	83.3	566	<50	886	659796	1453	1383	9412	<831	<166	14725
9A	93.1	42.56	1.00	22852	<10	57.1	123	566	<50	504	972499	2429	5213	24092	<2128	<426	21439
10A	97.3	52.34	1.00	18994	<10	59.0	128	276	<50	484	994113	3088	6713	14465	<2617	<523	25335
11A	101.7	31.78	1.00	9524	<1	<10	130	46.8	<50	130	302677	318	4121	1486	<1589	<31.8	4130
12A	105.6	4.69	1.00	1535	<1	<1	23.3	31.4	<5	100	7191	<46.9	109	147	<23.4	<4.69	467
13A	113.8	13.38	1.02	22223	<10	72.5	213	293	<50	704	297334	970	2846	3923	<669	<134	9418
14A	122.0	8.69	1.04	21496	<10	46.3	187	339	<50	389	186815	402	1624	2945	<435	<86.9	3381
14A-Dup	122.0	8.38	1.00	24084	<10	31.9	212	387	<50	436	201786	267	1773	3246	<419	<83.8	3650
15A	130.1	5.74	1.00	34574	<10	34.4	331	507	<50	541	198485	198	1903	2908	<287	<57.4	3104
16A	138.2	13.31	1.00	4193	<1	<10	56.2	11.4	<5	219	55822	<133	749	151	<66.6	<13.3	2914
17A	144.6	5.08	1.00	2395	<1	<1	34.7	11.6	<5	123	12155	<5.08	176	59.1	<25.4	<5.08	622

\*Alk = alkalinity as mg/L of CaCO<sub>3</sub>.  
ND = not determined.

**Figure B.20. Anions Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**

Insert Figure B.20.

**Table B.15. Calculated Porewater Cation Composition from Water Extracts  
of Vadose Zone Sediments from SX-108 Slant Borehole**

Sample ID	Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Aluminum (µg/L)	Barium (µg/L)	Calcium (mg/L)	Iron (µg/L)	Potassium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (µg/L)	Sulfate (mg/L)	Manganese (µg/L)
1A	55.1	23.13	1.00	16351	(375)	28.23	16197	(77)	(5.7)	2378	420	(259)	451	(585)
1A-Dup	55.1	23.13	1.00	15702	(409)	25.51	14623	(82)	(5.3)	2344	398	<23130	427	(526)
3A	67.9	36.88	1.02	66585	1073	(34.97)	67342	(131)	27.18	6829	734	(265)	855	(1349)
4A	72.2	36.15	1.00	50399	(819)	(32.95)	56108	(86)	(16.9)	7195	865	<36150	526	(882)
5A	76.4	21.36	1.00	26641	(468)	(17.97)	29374	(43)	(4.8)	5716	367	<21360	657	(375)
6A	80.6	27.18	1.00	10769	(223)	1647.9	9997	703	101	153069	(193)	(8131)	2329	<1359
7A	84.8	16.20	1.00	8598	2809	39.59	8481	1339	(3.3)	345472	170.3	(2794)	10402	<810
8A	89.0	16.61	1.00	(3405)	(207)	1966	(3397)	2961	118	305019	(99)	31612	10320	<831
9A	93.1	42.56	1.00	(4924)	(527)	4303	(5271)	4388	151	370034	(225)	45684	22196	<2128
10A	97.3	52.34	1.00	(11869)	1695	1821.3	(12356)	3604	128	391103	(295)	(36890)	13276	<2617
11A	101.7	31.78	1.00	<7945	29778	37905	<7945	1358	3143	65257	(285)	421747	1902	1813
12A	105.6	4.69	1.00	(929)	1739	1309	(929)	87	213	691	66	7485	113	(91)
13A	113.8	13.38	1.02	(2006)	548	1583	(2124)	1001	137	110749	(102)	23332	3600	<669
14A	122.0	8.69	1.04	(1297)	653	1678	(1297)	566	163	68587	(74)	27027	2836	<435
14A-Dup	122.0	8.38	1.00	(1146)	587	1855	(1125)	611	175	73859	(71)	29976	3042	<419
15A	130.1	5.74	1.00	(370)	507	2555	(357)	555	270	70723	82	37277	2891	<287
16A	138.2	13.31	1.00	(577)	18286	10030	(577)	348	2259	4404	164	64992	147	2287
17A	144.6	5.08	1.00	(412)	3519	2169	(412)	113	593	649	60	11816	59	541

Notes: In Sample ID column, Dup represents a duplicate water extract on a separate aliquot of sediment. Note that some analytes are reported as µg/L and others as mg/L. Depth represents the vertical depth in feet.; the S values have been converted to sulfate to allow comparison to the anion data in Table 4.4.

**Figure B.21. Cations Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**

Insert Figure B.21.



**Table B.16. Gamma Energy Analysis of Vadose Zone  
Sediments at SX-108 Slant Borehole**

Sample ID	Depth (ft bgs)	Cesium-137	± uncertainty	Potassium-40	± uncertainty
		pCi/g		pCi/g	
Hanford Subunit H1a (Sand)					
1A	55.1	3.06E+06	8.55E+04	<3.88E+03	--
Hanford Subunit H1 (Coarse Sand/Gravel)					
3BA	67.9	1.94E+07	5.37E+05	<1.45E+04	--
4B	71.5	8.16E+06	2.27E+05	<7.66E+03	--
4A	72.2	1.38E+06	3.94E+04	<7.21E+03	--
Hanford Subunit H2 (Fine Laminated Sand)					
5B	75.7	3.78E+06	1.05E+05	<6.40E+03	--
5A	76.4	6.52E+06	1.81E+05	<2.59E+04	--
6B	79.9	3.63E+07	1.64E+06	<4.17E+04	--
6A	80.6	5.31E+07	2.41E+06	<6.29E+04	--
7B	84.1	8.06E+06	2.26E+05	<4.16E+04	--
7A	84.8	2.14E+07	5.97E+05	<5.20E+04	--
7A1	84.6	9.57E+07	4.34E+06	--	--
8B	88.3	5.03E+06	1.41E+05	<9.86E+03	--
8A	89.0	5.55E+05	1.69E+04	<1.22E+03	--
9B	92.5	1.29E+04	1.91E+02	1.23E+01	3.19E+00
9A	93.1	1.71E+02	3.28E+00	2.49E+01	4.40E+00
10B	96.6	6.31E+02	1.00E+01	1.55E+01	1.45E+00
10A	97.3	4.51E+02	7.23E+00	1.82E+01	1.52E+00
11B	101	1.19E+04	1.86E+02	<2.46E+01	--
11A	101.7	9.12E+02	1.46E+01	2.73E+01	3.55E+00
12B	104.9	7.81E+02	1.23E+01	2.20E+01	2.82E+00
12A	105.6	3.37E+02	5.50E+00	2.66E+01	3.58E+00
13B	113.1	5.82E+03	8.95E+01	2.01E+01	3.08E+00
13A	113.8	5.21E+02	8.12E+00	1.64E+01	1.83E+00
14B	121.3	1.16E+03	1.78E+01	1.98E+01	3.37E+00
14A	122.0	8.37E+02	2.40E+01	3.01E+01	2.70E+00
Plio-Pleistocene Subunit (Fine-Grained Mud) [PPlz]					
15B	129.4	5.31E+02	8.65E+00	2.53E+01	5.50E+00
15A	130.1	5.92E+02	9.78E+00	2.47E+01	1.66E+00
16B	137.5	4.62E+03	7.13E+01	2.57E+01	4.11E+00
16A	138.2	9.79E+01	2.09E+00	2.52E+01	1.94E+00
17B	144	7.43E+02	1.17E+01	2.05E+01	5.16E+00
17A	144.6	1.75E+02	3.08E+00	2.58E+01	3.25E+00

**Figure B.22. Cesium-137 in Vadose Sediments at the SX-108 Slant Borehole**

Insert Figure B.22.

Technetium-99 is found at elevated concentrations throughout the SX-108 slant borehole. The technetium-99 elevated concentration pattern (listed as pCi/mL in Table B.17) shows an apparent bimodal distribution in the primary high contamination zone between 26 and 40 m [85 and 130 ft] bgs in the bottom half of subunit H2 and in subunit PPlz (Figure B.23). As with other constituents, the low technetium-99 concentration at 32 m (105.6 ft) bgs creates this distribution. The largest concentration peak occurs at 30 m (97 ft) bgs at a maximum concentration of about 237,000 pCi/mL. This pattern closely mimics the nitrate concentration distribution. It is probable that the bottom of the technetium-99 range was not reached in this sampling effort. Chromium concentration values (listed as mg/L in Table B.17) increase above background beginning at 20 m (68 ft) bgs and show maximum values between 25 and 40 m (81 and 130 ft) bgs. The peak concentrations of greater than 22,000 mg/L occur at 30 m (97 ft) bgs. The deepest entire chromium range may have been captured by these soil samples as indicated by very small concentrations in the two deepest samples. The occurrence of the maximum chromium range slightly higher in the soil column relative to technetium-99 indicates some retarding chemical mechanism has slowed chromium migration relative to technetium-99. Work completed by the S&T activity (Appendix D, Section D.4.1) indicates that iron(II)-rich minerals in the vadose zone soil reduce the oxidation state of a fraction of the chromium in solution from +6 to +3. In the +3 state, chromium is removed from solution by sorption or coprecipitation in iron(II)-rich minerals.

Other constituents that may have been placed into the soil column by the tank SX-108 leak include iodine-129, selenium, and molybdenum. The iodine-129 measurements are difficult to obtain and often suspect, but in this case there does appear to be measurable concentrations between 24 and 40 m (80 and 130 ft) bgs in 4 samples. The maximum concentration of about 43,000 pCi/L occurs at 24 m (80 ft) bgs and values decrease to about 19,000 pCi/L at the bottom of the SX-108 slant borehole, suggesting that the bottom of the iodine-129 contamination zone occurs below the borehole. These concentrations are three orders of magnitude less than technetium-99 concentrations in the same depth interval. Elevated selenium concentrations show a pattern that is nearly identical to technetium-99. Elevated molybdenum concentrations are more restricted and lie between 24 and 28 m (80 and 93 ft) bgs.

#### **B.4.4 CONTAMINANT CONCENTRATIONS**

Contaminant concentrations at the SX-108 slant borehole were not analyzed.

#### **B.4.5 CHEMICAL INTERACTIONS**

No specific experiments were completed on soils from the SX-108 slant borehole to quantify geochemical reactions influencing contaminant migration. Dominant chemical reactions affecting radionuclides and tank fluid chemicals are inferred from the relative location of these constituents in the soil column, comparison of acid-leachable versus water-leachable concentrations for specific contaminants, and general knowledge of the tank fluid chemistry. Greater contaminant mobility is inferred from the occurrence of high concentration zones deeper in the vadose zone and smaller differences in dissolved concentrations leached by water versus acid. Empirical in situ distribution coefficient estimates are summarized in Table B.18.

**Table B.17. Calculated Porewater Trace Metal Composition for Water Extracts of Sediments from SX-108 Slant Borehole**

Sample ID	Vertical Depth (ft bgs)	Dilution Factor	Water:Soil Ratio	Tc-99 (pCi/mL)	U (µg/L)	Cr* (mg/L)	As (µg/L)	Se (µg/L)	Mo (µg/L)	Ag (µg/L)	Cd (µg/L)	Pb (µg/L)
1A	55.1	23.13	1.00	<392	(35.9)	(0.21)	(875)	<1157	305	(2.31)	(30.1)	253389
1A-Dup	55.1	23.13	1.00	<392	(28.9)	(0.22)	(798)	<1157	347	<57.8	<57.8	4196
3A	67.9	36.88	1.02	(125)	140.14	(29.1)	(1239)	<1844	11446	<92.2	(3.69)	(679)
4A	72.2	36.15	1.00	(61)	209.67	(27.8)	(3687)	<1808	2176	<90.4	<90.4	(95.8)
5A	76.4	21.36	1.00	(217)	(98.3)	75.1	(1772)	(145)	3036	(32.0)	<53.4	(334)
6A	80.6	27.18	1.00	1106	(32.6)	13150	(266)	(1298)	127610	(216)	279	(78.8)
7A	84.8	16.20	1.00	16485	1433.7	5018	(2019)	984.2	90874	(183)	211	(953)
8A	89.0	16.61	1.00	47439	(43.2)	13782	(507)	2477	40238	(276)	105	(74.7)
9A	93.1	42.56	1.00	168400	(46.8)	21817	(1290)	5612	7510	(12.8)	(4.26)	(1221)
10A	97.3	52.34	1.00	237279	(55.0)	20838	(1675)	8615	871	(15.7)	<131	(325)
11A	101.7	31.78	1.00	144287	(6.36)	28.1	(753)	3849	184	<79.5	<79.5	(89.0)
12A	105.6	4.69	1.00	2792	(2.35)	0.98	(23.5)	(37.5)	56.7	<11.7	<11.7	(9.8)
13A	113.8	13.38	1.02	96874	(13.4)	5766	(561)	3182	3180	(8.03)	(14.7)	(33.5)
14A	122.0	8.69	1.04	58820	(5.65)	2588	(422)	1954	258	(5.21)	(0.87)	(45.2)
14A-Dup	122.0	8.38	1.00	64773	(7.12)	2913	(440)	2249	231	(5.03)	<21.0	(21.8)
15A	130.1	5.74	1.00	66072	6.89	1931	(443)	2360	78.6	(3.44)	(0.00)	(12.6)
16A	138.2	13.31	1.00	19255	(18.6)	(0.26)	(82.5)	(419)	181	<33.3	(2.66)	(58.6)
17A	144.6	5.08	1.00	2800	5.08	(0.02)	(20.8)	(69.1)	100	(0.51)	<12.7	(26.9)

Note: Values in parentheses are those that are below limit of quantification.

\*Higher chromium values are from ICP-OES, not ICP-MS. Note chromium values are in mg/L.

ICP = inductively coupled plasma.

MS = mass spectrometer.

OES = optical emission spectroscopy.

**Figure B.23. Trace Metals Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**

Insert Figure B.23.

**Table B.18. In Situ Distribution Coefficient Values for Contaminants  
Desorbing from SX-108 Slant Borehole Vadose Zone Sediments**

Sample ID	Depth (ft bgs)	Lith. Unit	Distribution Coefficient Values (mL/g)						
			Cesium-137	Technetium-99	Uranium	Chromium	Arsenic	Selenium	Molybdenum
01A	55.1	H1a	230.3	indeterm.	13	423	3.02	indeterm.	1.53
01A-dup	55.1	H1a	--	indeterm.	14	749	8.34	0.11	18.26
03A	67.9	H1	25.7	0.04	5	4.26	1.44	indeterm.	0.16
04A	72.2	H2	72.9	indeterm.	3	4.32	0.64	indeterm.	0.42
05A	76.4	H2	99.3	-0.01	8	2.92	2.68	1.26	0.44
06A	80.6	H2	2.3	0.01	24	0.01	16	0.11	0.06
07A	84.8	H2	4.2	-0.01	0	0.18	2.37	0.21	0.00
08A	89	H2	24.8	-0.02	18	0.05	10	0.06	0.19
09A	93.1	H2	6.5	0.00	14	0.01	3.38	0.02	0.04
10A	97.3	H2	10.2	0.00	12	0.01	2.49	0.02	0.46
11A	101.7	H2	>49.7	0.00	114	1.04	5.74	0.04	3.01
12A	105.6	H2	>120.7	-0.02	588	24.1	461	7.52	4.72
13A	113.8	H2	>46.5	0.00	459	0.04	10	0.06	0.79
14A	122	H2	307.4	0.01	168	0.06	14	0.10	3.21
14A-dup	122	H2	--	-0.01	132	0.03	13	0.12	3.36
15A	130.1	PPlz	>136.7	-0.02	139	0.04	8.32	0.10	7.84
16A	138.2	PPlz	>13.9	0.02	63	84.9	39	0.55	3.02
17A	144.6	PPlz	35.6	0.11	223	1864	303	4.58	15.7

Generally speaking, the data suggest that tank SX-108 fluid chemistry had a substantial, but limited, effect on contamination behavior at the SX-108 slant borehole. Given the depth below the tank SX-108 bottom at which very high concentrations of cesium-137 occur (essentially, the entire thickness of subunit H2), cesium-137 was initially highly mobile in the leaked tank fluid. Various types of sorption experiments completed by the S&T group (Appendix D, Section D.3.0) shows that the very high concentrations of cesium-137, sodium, and to a lesser extent potassium in the tank SX-108 fluid created local conditions where sodium preferentially occupied soil sorption sites in soils and preventing cesium-137 sorption. These conditions were short-lived and confined to subunits H1 and H2 as shown by the current limited distribution of cesium-137. Over time natural infiltration and recharge subsequently separated sodium from cesium-137, permitting cesium-137 to sorb in situ. The current degree of cesium-137 mobility was determined by comparing the amount of cesium-137 removed by water versus total activity measured by gamma. The in situ distribution coefficient for cesium-137 varies from about 2 to 300 mL/g in the sediments in the borehole where distribution coefficient values tend to correspond inversely to the salinity level.

Tank fluids also increased amounts of other constituents in the soil column, but had little effect on the chemical behavior of contaminants other than cesium-137 in the sense that chemical reactions between tank fluid constituents and the soil column environment were largely controlled by soil-soil water reactions. Constituent anions (e.g., nitrate and technetium-99) have migrated the most rapidly and mark the leading edge of vertical tank fluid migration. The technetium-99 in situ distribution coefficient was determined by comparing acid versus water leached concentrations and does not exceed 0.11 mL/g over the whole zone of contamination. Chromium was slightly retarded relative to technetium-99 and nitrate, presumably because of oxidation reduction, allowing fixation on soil. Generally, the in situ distribution coefficient values were very small except for the soil samples between 17 and 23 m (55 and 76 ft) bgs where the distribution coefficient value between about 3 and 430 mL/g was estimated. These numbers suggest that maximum oxidation reduction occurred near the tank bottom.

Other constituent cations have migrated varying distances depending on the strength of retardation mechanisms. Sodium concentrations, being relatively high, successfully completed for sorption sites in vadose zone soils, were somewhat retarded. Calcium, magnesium, and indigenous strontium were displaced by sodium and pushed ahead of sodium during migration.

#### **B.4.6 GROUNDWATER MEASUREMENTS**

Groundwater measurements were not taken at the SX-108 slant borehole.

## B.5.0 BOREHOLE SEDIMENT ANALYSIS

This section summarizes data reported in *Characterization of Uncontaminated Sediments from the Hanford Reservation – RCRA Borehole Core and Composite Samples* (Serne et al. 2001a) taken from two boreholes (299-W22-48 and 299-W22-50) drilled east of the S and SX tank farms (Figure B.1) as RCRA groundwater monitoring wells. Relative to vadose zone characterization, soil samples taken in the vadose zone represent undisturbed soils that have the soil characteristics found under the S and SX tank farms prior to contamination from tank leaks. The most important data collected from these boreholes include the physical soil properties and the porewater chemistry derived from water extractions, acid extractions, and porewater squeezings.

### B.5.1 GEOLOGY

Geology at boreholes 299-W22-48 and 299-W22-50 are described in the following sections.

#### B.5.1.1 Borehole 299-W22-48

Borehole 299-W22-48 was drilled for the RCRA Groundwater Monitoring Project. Samples were collected via continuous split spoon to a depth of 59 m (193.5 ft) bgs; the sampling effort was sponsored by the S&T activity. Grab samples were taken at 1.5 m (5 ft) intervals. Samples were obtained to support S&T activity research addressing characteristics of noncontaminated sediments.

**B.5.1.1.1 Hanford formation.** Sediments of the Hanford formation were penetrated from the surface to 41.3 m (135 ft) bgs. Subunits H1 and H2 were present.

- **Subunit H1** – Two distinct coarse-grained intervals (gravelly sand to gravel) were identified within relatively uniform medium-grained sand; an upper zone at 12.5 to 15.3 m (41 to 50 ft) bgs and a lower zone at 17.7 to 18.6 m (58 to 61 ft) bgs. These gravelly intervals have been identified in surrounding vadose zone boreholes and wells based on geophysical log correlations (Sobczyk 2000) but have not been readily identified in the geologic grab samples. The base of subunit H1 is estimated to lie at 18.6 m (61 ft) bgs.
- **Subunit H2** – Subunit H2 extends to 41.3 m (135 ft) bgs, and has been described as a fine to medium-grained sand which becomes finer with depth. Numerous silt laminae are noted in the split-spoon samples collected from this subunit at this location.

**B.5.1.1.2 Plio-Pleistocene Unit.** The two Plio-Pleistocene subunits include the upper subunit PPlz, characterized by a relatively high silt content, and the lower subunit PPlc, characterized by secondary, pedogenic, calcium-carbonate cement.

- **Subunit PPlz** – Subunit PPlz is recognized on the gamma logs and is present from 41.3 to 44.6 m (135 to 146 ft) bgs. This gamma signature reflects the downward decreasing grain size from silty sand to silt typical of the unit in this area.



- **Subunit PPlc** – Subunit PPlc is present from 44.6 to 45.5 m (146 to 149 ft) bgs at this location. The carbonate-rich unit is at a moderately higher elevation at this location than at sites further south.

**B.5.1.1.3 Ringold Formation.** Two subunits of the Ringold Formation have been tentatively identified at borehole 299-W22-48, the member of Taylor Flat and the member of Wooded Island. The interpretation of the Ringold Formation in this borehole differs significantly from other nearby wells.

- **Member of Taylor Flat** – At borehole 299-W22-48, a fairly uniform, silty, sandy, gravel unit extending from 45.5 to 58.6 m (149 to 192 ft) bgs has been tentatively identified as the member of Taylor Flat. This unit has not been identified elsewhere in the near vicinity and may actually be representative of the more commonly identified member of Wooded Island unit E.
- **Member of Wooded Island** – Member of Wooded Island unit E silty-sandy gravels have been identified by an increase in moisture at 58.6 m (192 ft) bgs that extends to the water table at 69 m (226 ft) bgs.

#### **B.5.1.2 Borehole 299-W22-50**

The vadose zone portion of borehole 299-W22-50 penetrated strata belonging to the Hanford formation, the Plio-Pleistocene unit, and the Ringold Formation. The upper 6.1 m (20 ft) of this borehole were not sampled, drilling in this portion of the borehole was done with a cable-tool deployed core barrel, and no intact samples were available for geologic logging. Field descriptions of that portion of the borehole indicate it penetrated fine sand, coarse sand, and gravel/sand facies.

**B.5.1.2.1 Hanford formation.** Sediments of the Hanford formation were penetrated from the ground surface to an estimated depth of 39.3 m (129 ft) bgs. Subunits H1 and H2 were present.

- **Subunit H1** – From a depth of 6.1 m (20 ft) bgs to approximately 16.1 m (53 ft) bgs the sediments logged consist of fine sand facies with lesser coarse sand facies. Stratification commonly observed in this interval include planar laminae, normally graded bedding and silty interbeds. Some evidence of planar and trough cross-bedding in the form of low-angle bedding intersections were observed. A few structures suggestive of clay skins on clastic dikes were noted. Minor pebble gravel, occurring as isolated clasts, is found in the lowermost 0.9 m (3 ft) of the interval.

Approximately 2.9 m (9.5 ft) of the gravel/sand facies underlies the sandy strata. The contact between these intervals is relatively sharp. Evidence of poorly developed planar and low angle bedding, suggested by coarse-fine grain size alterations is present. No clast-supported pebble gravel was observed in this interval.

- **Subunit H2** – A sandy interval from 19 to 39.3 m (62.5 to 129 ft) bgs is interpreted to be subunit H2. The upper 1.7 m (5.5 ft) consist predominately of well-stratified, friable, coarse sand. This sand appears to be unweathered and displays a mixed mafic/felsic mineralogy similar to the matrix sand in the overlying gravelly interval. The remainder

of this sand interval consists predominantly of planar laminated to ripple cross-laminated fine sand facies. Other observed stratification includes normally graded bedding, planar cross bedding and trough cross bedding. Two paleosols are present in the sandy interval at 22.9 m (75 ft) bgs and 31.4 m (103 ft) bgs. Poorly developed blocky peds, possible burrow traces, organic debris, and increased calcium carbonate content is evident in the uppermost of the two paleosols. The deeper paleosol is less well developed, displaying poorly developed traces of burrowing and mottling.

**B.5.1.2.2 Plio-Pleistocene Unit.** The two Plio-Pleistocene subunits include the upper subunit PPlz, characterized by a relatively high silt content, and the lower subunit PPlc, characterized by secondary, pedogenic, calcium-carbonate cement.

- **Subunit PPlz** – A fine sand/silt facies becomes dominant at 39.3 m (129 ft) bgs. This facies is consistent with the unit described as subunit PPlz in other boreholes in the vicinity of borehole 299-W22-50. This facies displays an increase in the occurrence of silt and the appearance of intercalated silt facies horizons greater than 0.15 m (0.5 ft) thick. Ripple cross-lamination and planar laminae are well developed in the sandy portions of the interval, which extends to 41.9 m (137.5 ft) bgs.
- **Subunit PPlc** – A well-developed paleosol at 41.9 m (137.5 ft) bgs marks the top of subunit PPlc. This paleosol is 0.15 m (0.5 ft) thick and displays moderately well developed beds, bedding is disrupted to massive, and stage I/II calcium carbonate is present. The remainder of the carbonate-rich interval consists of approximately 1.4 m (4.5 ft) of silt, sand, and gravel divided into: (1) approximately 0.46 m (1.5 ft) of conglomerate with a carbonate overprint; (2) somewhat greater than 0.3 m (1 ft) of silty paleosol; and (3) a basal conglomerate with carbonate overprint. The presence of stage II/III carbonate in the form of clast coatings, discontinuous stringers, and concretions indicates this is the Plio-Pleistocene carbonate rich subunit PPlc.

**B.5.1.2.3 Ringold Formation.** The top of the Ringold Formation is encountered at 43.4 m (142.5 ft) bgs where calcium carbonate content decreases markedly. The uppermost Ringold Formation strata encountered in this well consist of variably indurated conglomerate about 3.7 m (12 ft) thick that has a mixed basaltic/felsic sand matrix. The more felsic portions of the interval display yellow to yellow-brown color typical of many Ringold Formation deposits. However, the mafic content of these sediments is high enough to give the sand matrix a non-typical salt and pepper appearance.

In the interval 47.1 to 49.7 m (154.5 to 163 ft) bgs, coarse, variably indurated, crudely stratified sand with minor pebbles is present. The mineralogy of this sand is similar to the matrix sand in the overlying conglomerate. From 49.7 to 50.5 m (163 to 165.5 ft) bgs another conglomerate unit is penetrated. From 50.5 to 53.8 m (165.5 to 175 ft) bgs a sandy unit is present. This sandy unit is locally silty and displays abundant evidence of disrupted bedding and a white-gray color in the silty parts. The sand is calcium carbonate poor and the mafic content is greater than 25%.

At 53.5 m (175 ft) bgs conglomerate was again encountered, and at 53.8 ft (176.5 ft) bgs split-spoon sampling was suspended. Based on the abundance of gravel and absence of paleosol

facies in the Ringold Formation in this borehole the entire interval is assigned to the member of Wooded Island unit E.

## **B.5.2 GEOPHYSICAL AND PHYSICAL PROPERTY MEASUREMENTS**

Downhole geophysical and physical measurements (Figures B.24 and B.25) for the RCRA borehole sediments analysis included high-purity germanium spectral gamma logs; laboratory measurements of soil moisture content, neutron-neutron logs from the surface to the unconfined aquifer of both boreholes (249 ft [76 m] and 247 ft [75m] for 299-W22-48 and 299-W22-50, respectively); and soil suction measurements (Figure B.12). Outstanding geophysical data that distinguish stratigraphic units in the vadose zone include high moisture content and low natural gamma levels in subunit PPlc. Subunit PPlz shows relatively high natural gamma levels and low moisture content. Small silt-rich zones are indicated in subunit H2 by high moisture content. Soil suction measurements generally show drainage in the Hanford formation but not in the Plio-Pleistocene unit and below.

## **B.5.3 SOIL WATER CHEMISTRY MEASUREMENTS**

In addition to soil physical property measurements (Section B.5.2), an extensive water chemistry analysis has been completed for samples collected between the surface and 59 m (192 ft) bgs in borehole 299-W22-48 and between the surface and 53 m (174 ft) bgs for borehole 299-W22-50. The primary means of measuring porewater composition was to add deionized water to soil samples to generate enough water for performing analyses. By back-calculating for the dilution introduced by the added water, 'true' concentrations were derived. For a few samples porewater was directly separated from the same soil sample or one nearby and analyzed directly. By comparing the dilution-corrected water extract data with the porewater data in these few samples, an indication of the closeness of the water extract chemistry to original water chemistry was determined. In general, comparisons were not exact but concentration values were generally within a factor of two or better, agreement improved with increasing constituent concentration, and both sets of data showed similar concentrations versus soil depth correlations. Thus, the water extract method is an effective tool for evaluating tank fluid interactions with vadose zone soil.

Water extract pH and electrical conductivity measurements with depth are listed and graphed in Table B.19 and Figure B.26 for borehole 299-W22-48 and listed in Table B.20 for borehole 299-W22-50. The pH values in both boreholes fall into a normal range (7 to 8.5) except at 18 to 21 m (60 to 68 ft) bgs in borehole 299-W22-50 where elevated pH values (about 10 and 9) are measured. The reason for this increase is not known. Elevations in electrical conductivity values are not observed. A range of 50 to 500  $\mu\text{S}/\text{cm}$  are present in these samples.

Water extract anion concentrations as a function of depth are listed in Table B.19 for borehole 299-W22-48. Nitrate, chloride, and sulfate concentrations with depth are shown in Figure B.27. Other than enrichment of subunit PPlc in nitrate and sulfate, the profiles are undistinguished. In borehole 299-W22-50, anion data have no distinguishing features other than slight elevations of nitrate and sulfate in subunits PPlz and PPlc.

**Figure B.24. Vadose Zone Stratigraphy for Borehole 299-W22-48**

Insert Figure B.24.

**Figure B.25. Vadose Zone Stratigraphy for Borehole 299-W22-50**

Insert Figure B.25.

**Table B.19. Borehole 299-W22-48 pH, Electrical Conductivity, Alkalinity, and Anions in 1:1 Water Extracts (2 Sheets)**

Constituent Sample		pH	EC ( $\mu$ S/cm)	Alk (mg/L CaCO <sub>3</sub> )	F (mg/L)	Cl (mg/L)	NO <sub>2</sub> (mg/L)	NO <sub>3</sub> (mg/L)	PO <sub>4</sub> (mg/L)	SO <sub>4</sub> (mg/L)
Depth (ft bgs)	Strat. Unit									
1	H1a				1.56	1.27	<0.1	7.06	0.21	2.42
6	H1a				1.90	0.42	<0.1	7.94	<0.1	5.48
9.5	H1a				1.43	0.39	<0.1	5.89	0.27	8.79
12.5	H1a				3.04	0.32	<0.1	4.37	0.24	5.64
14.5	H1a				2.65	0.30	<0.1	4.46	0.29	14.62
17	H1a				2.66	0.35	<0.1	7.10	0.37	15.20
19.5	H1a				1.74	0.72	<0.1	9.79	<0.1	15.70
22	H1a				1.03	0.49	<0.1	14.50	0.35	16.90
24.5	H1a				0.95	0.37	<0.1	5.27	0.34	18.20
27	H1a				1.39	0.49	<0.1	11.00	0.28	18.30
29.5	H1a	7.38	224	47.94	0.95*	0.32*	<0.1	7.89*	0.27*	20.68*
32	H1a	7.97	171	41.60	0.62	0.26	<0.1	6.97	0.30	9.14
34.3	H1a				0.79	0.39	<0.1	5.20	0.63	9.88
37	H1a				0.72	1.43	<0.1	11.90	0.28	14.80
39.5	H1a	7.39	180	33.14	0.55	0.65	<0.1	13.75	<0.24	14.75
42	H1				0.74	0.43	<0.1	3.99	0.13	11.85
44.5	H1				0.63	0.42	<0.1	3.69	0.18	18.40
47	H1	7.30	126	28.91	0.58**	0.24**	<0.1	2.76**	0.13	9.26**
50	H1				0.65	0.84	<0.1	10.90	0.25	12.10
53.5	H1				0.49	0.53	<0.1	2.46	<0.1	10.10
56	H1	7.20	142	NA	0.45	1.05	<0.1	1.00	0.13	11.47
57.5	H1				0.57	1.72	<0.1	7.07	0.12	13.40
74.5	H2	7.395	216	36.00	0.50	5.06	<0.1	7.28	0.33	24.06
91.5	H2				0.60	4.83	<0.1	8.44	0.39	13.60
101.5	H2				0.63	5.48	<0.1	9.82	0.34	17.15
106.5	H2	7.70	177	33.84	0.33	6.45	<0.1	5.19	<0.1	10.40
115.5	H2	7.39	182	38.07	0.36	2.28	<0.1	7.55	0.38	12.30
136	PPlz	7.20	214	40.19	0.45	1.32	<0.1	22.70	0.50	11.90
143.5	PPlz	7.12	186	34.55	0.27	0.71	<0.1	16.20	0.35	11.10
146	PPlc	7.39	441	47.47	0.91	3.57	<0.1	75.20	0.17	44.40
148.5	PPlc	7.48	291	41.6	1.27	1.84	<0.1	42.80	<0.1	16.90

**Table B.19. Borehole 299-W22-48 pH, Electrical Conductivity, Alkalinity, and Anions in 1:1 Water Extracts (2 Sheets)**

Constituent Sample		pH	EC ( $\mu$ S/cm)	Alk (mg/L CaCO <sub>3</sub> )	F (mg/L)	Cl (mg/L)	NO <sub>2</sub> (mg/L)	NO <sub>3</sub> (mg/L)	PO <sub>4</sub> (mg/L)	SO <sub>4</sub> (mg/L)
Depth (ft bgs)	Strat. Unit									
151	Rtf	7.56	208	49.35	1.21	1.68	<0.1	4.16	<0.1	5.45
163.5	Rtf	7.46	117	29.96	0.49	0.45	<0.1	6.95	0.11	1.69
170	Rtf	7.40	116	31.02	0.46	0.49	<0.1	7.34	0.21	1.84
172.5	Rtf	7.33	190	31.73	0.50	0.40	<0.1	1.96	<0.1	1.50
187	Rtf	7.58	53	15.51	0.48	0.59	<0.1	9.91	<0.1	1.86
192	Rwi(e)	7.78	120	18.33	1.37	1.55	<0.1	9.10	0.29	10.00

Note: \*Data in *italics* type are average of duplicate extracts. \*\*Data in **bold** type are the average of triplicate extracts.

EC = electrical conductivity.

NA = not analyzed.

**Figure B.26. Moisture Content (wt%) of Sediment, pH and Dilution-Corrected  
Electrical Conductivity of Water Extract and Actual Porewater  
versus Depth and Stratigraphy for Borehole 299-W22-48**

Insert Figure B.26.



**Table B.20. Borehole 299-W22-50 pH, Electrical Conductivity, Alkalinity, and Anions in 1:1 Water Extracts**

Constituent Sample		pH	EC ( $\mu$ S/cm)	Alk mg/L CaCO <sub>3</sub>	F (mg/L)	Cl (mg/L)	NO <sub>2</sub> (mg/L)	NO <sub>3</sub> (mg/L)	PO <sub>4</sub> (mg/L)	SO <sub>4</sub> (mg/L)
Depth (ft bgs)	Strat. Unit									
20	H1a	7.78	188	52.88	0.72	0.45	<0.1	5.89	0.1	8.56
22.5	H1a	7.72	221	26.79	0.74	1.08	<0.1	4.51	<0.1	13.52
25	H1a	7.68	214	31.73	0.72	0.76	<0.1	3.42	0.2	9.78
27.5	H1a	7.60	214	48.65	0.7	1.88	<0.1	0.63	0.1	19.56
30	H1a	7.65	217	39.48	0.63	4.85	<0.1	2.64	0.15	20.5
32.5	H1a	7.67	186	43.01	0.56	1.62	<0.1	2.51	0.33	11.64
35	H1a	7.49	222	50.06	0.68	0.82	<0.1	0.68	0.29	13.85
37.5	H1a	7.84	203	45.12	0.61	0.67	<0.1	0.57	<0.1	12.51
40	H1a	7.03	184	47.24	0.5	0.57	<0.1	0.36	<0.1	11.49
42.5	H1a	7.11	223	54.29	0.58	0.99	<0.1	1.15	0.16	17.54
45*	H1a	7.46 $\pm$ 0.1	224 $\pm$ 3	35 $\pm$ 19	0.60 $\pm$ 0.05	0.82 $\pm$ 0.01	<0.1	1.46 $\pm$ 0.52	<0.1	17.6 $\pm$ 1.1
47.5	H1a	7.40	224	34.55	0.57	0.83	<0.1	0.46	<0.1	16.37
51	H1a	7.90	181	56.40	0.59	0.45	<0.1	3.09	0.1	8.62
52.5	H1a	7.44	181	32.43	0.39	0.85	<0.1	0.72	<0.1	16.15
55	H1	7.32	216	54.99	0.47	1.34	<0.1	0.25	<0.1	19.18
56	H1	7.35	129	25.38	0.28	0.54	<0.1	1.25	0.12	8.37
60	H1	10.33	553	60.63	0.41	9.33	<0.1	1.82	<0.1	35.71
67.5	H2	9.00	276		0.38	4.84	<0.1	5.49	0.21	21.9
76	H2	8.55	223	21.86	0.36	4.4	<0.1	8.85	0.18	29.7
96*	H2	7.44 $\pm$ 0.02	298 $\pm$ 15	35 $\pm$ 5	0.39 $\pm$ 0.06	23.7 $\pm$ 13	<0.1	10.0 $\pm$ 1.0	0.20 $\pm$ 0.06	28.7 $\pm$ 1.0
111	H2	7.45	296	58.52	0.49	11.47	<0.1	25.51	0.15	23.01
115	H2	7.51	309	55.70	0.51	14.41	<0.1	29.8	0.17	16.6
130	PPlz	7.66	231	89.54	0.41	2.01	<0.1	6.32	0.16	9.63
135	PPlz	8.50	226.5	62.04	0.46	2.31	<0.1	20.99	0.2	18.02
141	PPlc	8.12	246	67 $\pm$ 36	0.80 $\pm$ 0.08	3.3 $\pm$ 0.5	<0.1	11 $\pm$ 1.3	<0.1	22 $\pm$ 2.8
150.5	Rtf	7.77	191	6.35	1.1	1.49	<0.1	<0.1	<0.1	8.62
160.5	Rtf	7.74	135	31.02	0.62	0.76	<0.1	<0.1	<0.1	3.13
174	Rtf	7.75	88	18.33	0.99	4.77	<0.1	10.9	0.13	2.57

\*Data are average of duplicate extracts.

EC = electrical conductivity.

**Figure B.27. Dilution-Corrected Anion Content of Water Extracts  
and Anion Concentration in Actual Porewater versus Depth  
and Stratigraphy for Borehole 299-W22-48**

Insert Figure B.27.

Water extract cation concentrations as a function of depth are listed in Table B.21 and graphed in Figure B.28 for borehole 299-W22-48. Table B.22 provides cation concentrations for borehole 299-W22-50. In both boreholes slight elevations of calcium and natural strontium occur in subunit PPlc because of the relatively high quantities of calcium carbonate. A calcium enrichment anomaly occurs at 60 ft (18 m) bgs in borehole 299-W22-50, which is unexplained.

Trace metal concentrations are shown in Tables B.23 and B.24 for boreholes 299-W22-48 and 299-W22-50, respectively. Slight molybdenum enrichment is seen in subunit PPlc at both boreholes. Also, in borehole 299-W22-48 slight enrichment of selenium occurs in subunit PPlc.

#### **B.5.4 CONTAMINANT CONCENTRATIONS**

Contaminant concentrations were not analyzed in the RCRA borehole sediments analysis.

#### **B.5.5 CHEMICAL INTERACTIONS**

Chemical interactions were not analyzed in the RCRA borehole sediments analysis.

#### **B.5.6 GROUNDWATER MEASUREMENTS**

Groundwater contaminants are present in boreholes 299-W22-48 and 299-W-22-50. The contaminants are apparently derived both from large regional contaminant plumes (whose sources are a variety of crib, ditch, and trench discharges) and from tank waste. Available contaminant data are listed in Appendix C, Table C.16. Small concentrations of technetium-99, chromium, nitrate, and carbon tetrachloride are present in borehole 299-W22-48. The carbon tetrachloride is ubiquitous in this region. Technetium-99 appears to be increasing and may be derived from S tank farm contamination. The carbon tetrachloride and the nitrate that occur 75 to 80 m (246 to 263 ft) bgs in well 299-W22-50 are assumed to be derived from regional sources. The technetium-99 and nitrate occurring near the top of the aquifer may be derived from the tank SX-115 leak as indicated by the elevated technetium-99/nitrate ratio of 0.1 pCi/ $\mu$ g the same ratio found at well 299-W23-19 (Figure C.25). A more extensive discussion of these and other data postulated as relevant to tank SX-115 leak is provided in Section 3.4.2 of the main text.

**Table B.21. Major Cations in 1:1 Water Extracts of Borehole 299-W22-48 Sediment Samples**

Stat Unit (ft bgs)	Na (mg/L)	Mg (mg/L)	Al (µg/L)	Si (mg/L)	P (µg/L)	S (mg/L)	K (mg/L)	Ca (mg/L)	Mn (µg/L)	Fe (µg/L)	Sr (µg/L)	Ba (µg/L)
29.5-H1a	28.97	1.42	(35)	17.71	(91)	7.18	4.67	6.78	(1)	49.2	29.7	27.6
32.0-H1a	21.10	1.16	(49)	16.46	(113)	2.95	4.12	6.00	(1)	68.8	21.1	12.2
39.5-H1a	20.09	1.24	(29)	10.57	<500	4.54	3.83	6.66	(1)	(17)	24.3	15.5
47.0-H1	12.70	1.07	(48)	10.46	(2)	3.26	2.93	5.28	(1)	42.5	25.4	21.2
56.0-H1	15.36	2.29	50.7	9.06	(135)	4.00	4.70	8.89	(3)	43.1	37.4	(5)
<b>74.5-H2</b>	<b>16.45</b>	<b>3.56</b>	<b>76.1</b>	<b>9.55</b>	<b>(83)</b>	<b>8.98</b>	<b>4.36</b>	<b>10.75</b>	<b>(1)</b>	<b>45.0</b>	<b>62.0</b>	<b>17.3</b>
91.5-H2	19.14	2.86	286	12.80	(197)	5.30	3.47	9.55	(2)	93.2	49.9	17.0
101.5-H2	20.19	2.75	272	13.64	(169)	6.36	3.45	11.95	(3)	90.9	59.3	29.9
106.5-H2	14.21	2.15	85.0	8.94	(36)	4.14	3.60	9.65	(1)	63.2	48.5	16.9
115.5-H2	14.81	2.27	54.8	11.33	(21)	4.94	3.36	10.47	(1)	58.7	57.1	27.9
136.0-PPlz	16.50	3.21	68.5	11.76	(110)	4.78	3.84	12.92	(1)	39.2	65.9	32.3
143.5-PPlz	11.32	3.66	(10)	8.83	(88)	4.21	3.27	11.23	(1)	(8)	61.0	29.5
<b>146.0-PPlc</b>	<b>22.44</b>	<b>12.21</b>	<b>(5)</b>	<b>26.28</b>	<b>(207)</b>	<b>15.83</b>	<b>5.00</b>	<b>29.60</b>	<b>(0)</b>	<b>(5)</b>	<b>186</b>	<b>29.6</b>
148.5-PPlc	15.29	7.52	(8)	28.10	<500	6.40	3.99	18.47	(0)	95.5	121	24.9
151.0-Rtf	17.55	4.70	(29)	18.91	(81)	2.39	6.11	10.39	(4)	(19)	60.9	16.5
163.5-Rtf	7.24	2.68	(25)	11.73	<500	0.83	2.47	6.65	(0)	(16)	38.2	11.9
170.0-Rtf	7.13	2.93	(31)	12.78	<500	0.89	2.82	7.30	(2)	33.2	41.3	44.6
172.5-Rtf	8.22	2.80	(29)	13.06	(18)	0.70	3.62	7.01	(1)	(21)	39.3	19.0
187.0-Rtf	4.74	0.51	(28)	12.70	(145)	0.77	1.58	1.31	(2)	46.3	(7)	(8)
192.0-Rwi(e)	13.95	0.74	65.2	11.65	(125)	3.84	4.22	1.75	(2)	40.7	(10)	16.5

Note: Values in parenthesis are just below level of quantification but spectra looked good; thus, a tentative value was attributed to data. Data in **bold** are average of duplicate extracts.

**Figure B.28. Dilution-Corrected Cation Content of Water Extracts and Cation Concentrations in Actual Porewater versus Depth for Borehole 299-W22-48**

Insert Figure B.28.

**Table B.22. Major Cations in 1:1 Water Extracts for Borehole 299-W22-50**

Depth (ft bgs)	Strat. Unit	Na mg/L	Mg mg/L	Al µg/L	Si mg/L	P µg/L	S mg/L	K mg/L	Ca mg/L	Mn µg/L	Fe µg/L	Sr µg/L	Ba µg/L
20	H1a	19.63	1.65	(29)	16.34	(33)	3.11	5.40	7.14	(0)	33.9	31.6	16.9
22.5	H1a	24.74	2.08	(45)	16.61	<500	4.76	6.48	9.49	(1)	96.2	40.2	20.0
25	H1a	20.05	1.40	(30)	14.22	(91)	3.51	5.41	6.32	(0)	30.6	27.5	18.5
27.5	H1a	22.40	2.35	(38)	15.60	(42)	7.10	6.69	10.72	(2)	76.7	48.1	28.8
30	H1a	20.15	2.42	(20)	17.47	(59)	7.18	5.98	11.24	(0)	45.6	52.1	19.9
32.5	H1a	19.79	1.67	(23)	15.40	(91)	4.48	4.86	7.95	(0)	26.3	34.6	18.2
35	H1a	25.40	2.15	(30)	16.63	(54)	5.56	6.82	10.91	(1)	31.7	49.0	26.3
37.5	H1a	22.52	1.97	(21)	16.02	(80)	5.08	6.37	9.98	(0)	33.2	44.7	19.8
40	H1a	18.18	2.07	(28)	15.41	(37)	4.72	6.18	9.98	(0)	27.5	46.3	23.5
42.5	H1a	22.12	2.62	(25)	17.63	<500	6.85	7.09	12.86	(0)	(22)	55.9	17.5
45	H1a	<b>21.62</b>	<b>2.52</b>	<b>(30)</b>	<b>18.01</b>	<b>(50)</b>	<b>7.06</b>	<b>7.19</b>	<b>12.28</b>	<b>(0)</b>	<b>(22)</b>	<b>55.5</b>	<b>21.3</b>
47.5	H1a	22.33	2.63	(25)	17.90	(41)	6.47	7.31	13.13	(0)	(23)	59.9	21.1
51	H1a	17.25	1.84	(22)	17.61	(126)	3.39	5.20	9.15	(0)	35.2	39.9	13.7
52.5	H1a	15.17	2.17	(34)	13.94	(52)	6.26	5.57	10.12	(0)	(19)	46.3	20.3
55	H1	19.45	2.79	(36)	15.40	(56)	7.31	6.56	12.72	(1)	33.7	58.3	27.5
56	H1	11.06	1.77	(47)	9.01	(76)	3.20	4.09	5.74	(1)	(21)	26.8	14.6
60	H1	28.12	0.03	379	28.04	(145)	13.61	10.05	51.55	<10	(7)	176	44.9
67.5	H2	16.36	3.03	103	10.67	(154)	8.21	4.69	12.62	(1)	109	56.8	15.3
76	H2	16.34	2.79	75.1	10.51	(81)	10.64	4.01	14.10	(0)	59.7	58.7	16.4
96	H2	<b>23.18</b>	<b>4.29</b>	<b>(27)</b>	<b>9.95</b>	<b>(139)</b>	<b>11.20</b>	<b>5.93</b>	<b>19.17</b>	<b>(0)</b>	<b>(18)</b>	<b>85.6</b>	<b>26.7</b>
111	H2	22.41	3.93	(14)	11.51	(67)	9.01	5.66	17.85	(0)	(11)	79.7	30.1
115	H2	24.33	4.15	(26)	10.23	(51)	6.75	5.49	18.50	(3)	33.1	85.4	35.5
116	H2	17.48	2.14	308	14.43	(257)	4.05	2.66	10.45	(2)	98.6	46.1	25.8
130	PPlz	18.37	4.03	(29)	9.96	(78)	4.13	3.78	16.15	(2)	(19)	71.8	28.6
135	PPlz	20.96	4.61	(13)	10.58	(179)	7.07	4.72	15.73	(0)	(12)	70.3	28.7
140	PPlc	17.01	3.51	277	14.99	(131)	6.16	3.04	11.41	(3)	117	57.4	34.0
141	PPlc	<b>20.13</b>	<b>5.28</b>	<b>(20)</b>	<b>21.56</b>	<b>(33)</b>	<b>8.93</b>	<b>4.71</b>	<b>17.09</b>	<b>(0)</b>	<b>(13)</b>	<b>82.9</b>	<b>22.7</b>
150.5	Rtf	17.33	3.31	370	13.81	(129)	3.87	4.63	10.44	15.2	352	59.6	15.3
160.5	Rtf	10.02	2.33	(38)	13.98	(88)	1.52	3.60	8.41	(2)	(24)	40.5	16.8
174	Rtf	6.69	0.90	106	13.81	(123)	1.13	2.20	2.98	(2)	44.7	(14)	(5)

Note: Values in parenthesis are just below level of quantification but spectra looked good; thus, a tentative value was attributed to data. Data in **bold** are the average of duplicate extractions.

**Table B.23. Trace Metals in 1:1 Water Extracts of Borehole 299-W22-48 Sediments**

<b>Units (ft bgs)</b>	<b>B (µg/L)</b>	<b>Cr* (µg/L)</b>	<b>Co (µg/L)</b>	<b>Ni (µg/L)</b>	<b>Cu (µg/L)</b>	<b>Zn (µg/L)</b>	<b>As* (µg/L)</b>	<b>Se* (µg/L)</b>	<b>Mo* (µg/L)</b>	<b>Tc* (µg/L)</b>	<b>Pb* (µg/L)</b>	<b>U* (µg/L)</b>
29.5-H1a	(8)	(0.32)	<10	<100	<25	30.9	37.5	(0.69)	3.97	(0.00)	(0.16)	2.84
32.0-H1a	(3)	(0.37)	1.4	<100	<25	15.0	32.1	(0.15)	2.35	(0.00)	(0.03)	1.47
39.5-H1a	(0)	(0.39)	<10	<100	<25	22.7	21.6	(1.06)	4.81	(0.00)	(0.29)	1.76
47.0-H1	<100	(0.19)	1.1	<100	<25	22.3	9.45	(0.29)	1.20	(0.00)	(0.25)	0.530
56.0-H1	(4)	(0.07)	1.0	<100	<25	16.3	9.52	(0.23)	11.35	(0.00)	(0.16)	1.47
<b>74.5-H2</b>	<b>(6)</b>	<b>0.470</b>	<b>&lt;10</b>	<b>&lt;100</b>	<b>&lt;25</b>	<b>23.1</b>	<b>21.6</b>	<b>(0.65)</b>	<b>7.08</b>	<b>(0.00)</b>	<b>(0.18)</b>	<b>0.430</b>
91.5-H2	2003	0.551	1.3	<100	<25	15.7	22.5	(3.84)	17.64	(0.00)		0.455
101.5-H2	1996	0.985	<10	<100	<25	20.0	19.2	5.77	24.2	<0.025		0.430
106.5-H2	(6)	0.530	<10	<100	<25	24.5	17.1	(2.25)	12.1	(0.00)	(0.22)	0.375
115.5-H2	(10)	0.940	1.8	<100	(0)	26.9	21.2	(3.15)	10.6	(0.00)	(0.31)	0.530
136.0-PPlz	(8)	0.665	1.5	<100	<25	44.1	26.4	12.9	9.5	(0.00)	(0.14)	0.510
143.5-PPlz	(7)	(0.21)	1.1	<100	<25	25.6	9.20	6.55	17.3	<0.025	(0.14)	0.970
<b>146.0-PPlc</b>	<b>(11)</b>	<b>1.86</b>	<b>1.4</b>	<b>&lt;100</b>	<b>&lt;25</b>	<b>29.3</b>	<b>8.44</b>	<b>36.50</b>	<b>57.2</b>	<b>(0.00)</b>	<b>(0.08)</b>	<b>7.90</b>
148.5-PPlc	(3)	0.690	<10	<100	<25	23.3	10.8	14.8	9.9	(0.00)	(0.75)	5.68
151.0-Rtf	(4)	(0.07)	0.9	<100	(2)	22.1	8.56	(3.22)	7.58	(0.00)	(0.04)	2.48
163.5-Rtf	<100	(0.05)	2.0	<100	<25	27.8	15.0	(2.67)	5.17	(0.00)	(0.01)	0.245
170.0-Rtf	(0)	(0.24)	0.0	<100	<25	86.8	12.4	(3.39)	5.99	<0.025	(0.22)	0.565
172.5-Rtf	(1)	(0.17)	2.2	<100	<25	23.8	10.6	(1.80)	6.94	(0.00)	(0.06)	0.920
187.0-Rtf	<100	(0.19)	1.4	<100	<25	26.3	6.31	4.25	3.54	(0.00)	(0.09)	0.000
192.0-Rwi(e)	(9)	(0.26)	0.8	<100	<25	96.7	6.80	5.78	7.14	<0.025	(0.13)	0.032

Note: Values in parenthesis are just below level of quantification but spectra looked good; thus, a tentative value was attributed to data. Data in **bold** are average of duplicate extractions.

\*ICP-MS instrument was used.

**Table B.24. Trace Metals in 1:1 Water Extracts of Samples for Borehole 299-W22-50**

Depth (ft bgs)	Strat. Unit	B (µg/L)	Cr* (µg/L)	Co (µg/L)	Ni (µg/L)	Cu (µg/L)	Zn (µg/L)	As* (µg/L)	Se* (µg/L)	Mo* (µg/L)	Tc* (µg/L)	Pb* (µg/L)	U* (µg/L)
20	H1a	(8)	0.910	<10	(6)	(1)	30.3	39.3	<5	1.89	(0.00)	(0.35)	1.11
22.5	H1a	(6)	(0.31)	0.5	(6)	(2)	41.4	34.4	<5	4.81	(0.00)	(0.28)	1.73
25	H1a	(4)	(0.28)	<10	(4)	(1)	48.8	41.3	(0.02)	3.52	(0.00)	(0.84)	1.55
27.5	H1a	(3)	(0.47)	0.1	(2)	(1)	33.6	34.0	(0.14)	6.57	(0.00)	(0.13)	1.44
30	H1a	(5)	(0.32)	<10	(3)	(2)	31.5	13.5	(0.27)	1.62	(0.00)	(0.09)	0.805
32.5	H1a	(3)	(0.41)	0.4	(3)	(1)	30.8	27.0	(0.24)	2.12	(0.00)	(0.01)	1.61
35	H1a	(2)	0.510	0.0	(2)	(1)	31.3	24.3	(0.28)	9.68	(0.00)	(0.03)	2.08
37.5	H1a	(3)	0.625	<10	(2)	(3)	28.6	22.8	(0.21)	12.8	(0.00)	(0.25)	1.72
40	H1a	(4)	0.535	<10	(3)	(1)	42.4	10.1	(0.07)	4.32	(0.00)	(0.02)	1.07
42.5	H1a	(6)	0.590	<10	(4)	(1)	46.7	11.5	(0.17)	6.74	(0.00)	(0.00)	1.15
45	H1a	<b>(5)</b>	<b>(0.49)</b>	<b>&lt;10</b>	<b>(2)</b>	<b>(3)</b>	<b>35.2</b>	<b>13.2</b>	<b>(0.58)</b>	<b>6.05</b>	<b>(0.00)</b>	<b>(0.22)</b>	<b>1.15</b>
47.5	H1a	(5)	(0.49)	<10	(3)	(1)	29.8	11.2	(0.13)	12.54	<0.02	(0.08)	1.21
51	H1a	(0)	(0.39)	<10	(3)	(0)	26.7	12.4	(0.18)	1.03	(0.00)	(0.00)	0.710
52.5	H1a	(2)	(0.32)	<10	(3)	<25	34.8	9.60	(0.50)	3.35	(0.00)	(0.25)	0.565
55	H1	(4)	(0.48)	<10	(4)	(2)	26.9	7.09	(0.31)	14.9	(0.00)	(0.02)	0.820
56	H1	<100	(0.15)	<10	(2)	<25	33.3	9.16	(0.42)	2.81	(0.00)	(0.02)	0.565
60	H1	(11)	48.8	<10	(2)	(3)	33.5	2.95	(0.66)	10.21	(0.00)	(0.02)	0.000
67.5	H2	(3)	0.715	<10	(4)	(2)	34.3	16.6	(0.66)	9.96	(0.00)	(0.21)	0.885
76	H2	(4)	0.760	<10	(4)	(0)	31.4	14.7	(1.14)	4.77	(0.00)	(0.14)	0.565
96	H2	<b>(11)</b>	<b>0.775</b>	<b>&lt;10</b>	<b>(2)</b>	<b>&lt;25</b>	<b>30.2</b>	<b>12.7</b>	<b>(1.22)</b>	<b>14.5</b>	<b>(0.00)</b>	<b>(0.10)</b>	<b>0.567</b>
111	H2	(12)	1.85	<10	(8)	(5)	27.7	13.8	(1.64)	20.2	(0.00)	(0.00)	0.615
115	H2	(14)	0.500	0.0	(6)	(4)	28.7	11.7	(3.40)	17.6	(0.00)	(0.05)	0.810
116	H2	2161	0.705	0.1	(3)	(4)	19.9	29.7	(1.43)	11.1	(0.00)		0.348
130	PPlz	(9)	(0.39)	<10	(3)	(4)	25.5	9.81	(3.12)	15.1	(0.00)	(0.02)	0.935
135	PPlz	(12)	1.65	<10	(5)	(3)	33.3	6.76	5.38	28.1	(0.00)	(0.07)	0.870
140	PPlc	2089	0.925	1.2	<100	(1)	21.1	9.51	(2.00)	25.7	(0.00)		0.975
141	PPlc	<b>(8)</b>	<b>0.725</b>	<b>&lt;10</b>	<b>(4)</b>	<b>(3)</b>	<b>34.9</b>	<b>18.1</b>	<b>(3.14)</b>	<b>63.6</b>	<b>(0.00)</b>	<b>(0.17)</b>	<b>10.24</b>
150.5	Rtf	(5)	0.565	<10	(5)	(3)	31.4	3.61	(0.10)	8.23	(0.00)	(0.10)	0.775
160.5	Rtf	(5)	(0.29)	0.0	(6)	(4)	30.8	3.82	(0.95)	5.96	(0.00)	(0.04)	0.438
174	Rtf	(1)	0.610	<10	(5)	(5)	32.0	3.44	(3.41)	1.61	(0.00)	(0.24)	0.005

Note: Values in parenthesis are just below level of quantification but spectra looked good; thus, a tentative value was attributed to data. Data in **bold** are average of duplicate extractions.

\*ICP-MS instrument was used.



## **B.6.0 S TANK FARM SHALLOW SOILS INVESTIGATION**

A shallow soils investigation (Bratton et al. 2001a) was conducted in the S tank farm to address the source and extent of contamination associated with tank S-104, as well as other nearby locations that could have contributed to the identified vadose zone contamination. Cesium-137 had been reported in the vicinity of this tank (GJPO 1998) through the baseline spectral gamma logging program. Cesium-137 was noted at concentrations greater than the resolution capability of the 35% high-purity germanium tool used. Research into the history of 241-S-104 operations revealed that the tank was subjected to an overfill in 1965. After thorough review of the tanks' construction, a hypothesis was developed that proposed that when the tank was overfilled, the resulting moderate overpressurization caused tank wastes to exit the tank through one or more spare inlet ports. The location of the well shown by the spectral gamma logging to be contaminated is in close proximity to a bank of spare inlet ports at the four o'clock position on the tank. This hypothesis could be tested by collecting gamma distribution data near the tank wall at this position.

A gamma tool deployed via a cone penetrometer was selected as the preferred method of collecting data. The cone penetrometer can be rapidly pushed to the depth of the tank farm excavation, gross gamma data collected as the cone is advanced and spectral gamma analysis could be run to determine those contaminants contributing to the gross gamma signature. Gamma spectra were obtained during this deployment, but are not reported due to the limited window of concentration that can be defined (Bratton et al. 2001b). Finally, it would be feasible to attempt collecting samples should threshold sampling criteria be met.

Eight locations (Figure B.29) were selected to be characterized. These locations were screened for underground utilities using ground-penetrating radar. These ground-penetrating radar screens revealed that the primary site was in close proximity to a shallow electrical service. This site was hand excavated to reveal the true location of the electrical service and then an elongate area demarked through which the cone penetrometer was deployed.

### **B.6.1 GEOLOGY**

The investigation only went through the backfill material. See Appendix C, Section C.4.0 for a description of the backfill.

### **B.6.2 GEOPHYSICAL AND PHYSICAL PROPERTY MEASUREMENTS**

Three locations (CP-04-03, CP-04-04, and CP-04-05) showed gross gamma signatures (Bratton et al. 2001a). Two of these locations (CP-04-04 and CP-04-05) show a bimodal distribution of gross gamma counts (Figures B.30 and B.31). The lowermost zone of high counts, present at all three locations, resides at the base of the tank farm excavation from 12.2 to 13.7 m (40 to 45 ft) bgs. Count rates in this zone ranged from 60,000 to 125,000 counts per second resulting in an instrument dead time exceeding 90%. The upper zone resides between 8.8 and 9.8 m (28.75 and 32 ft) bgs, well above and separated from the base of the excavation. The highest count rates in these two zones were 15,000 and 80,000 counts per second.

**Figure B.29. Cone Penetrometer Test Locations in the S Tank Farm**

Insert Figure B.29.

**Figure B.30. Distribution of Gross Gamma Concentrations at  
Location CP-04-04 Down to 50 ft (16 m) Below Ground Surface**

Insert Figure B.30.

**Figure B.31. Distribution of Gross Gamma Concentrations at  
Location CP-04-05 Down to 50 ft (16 m) Below Ground Surface**

Insert Figure B.31.

Samples were collected from immediately below the upper zones of contamination and submitted for laboratory analysis. Because the spectral gamma mode analysis of these portions of the holes did not show a characteristic peak for cesium, the possibility of strontium-90 based Brehmsstrahlung-induced peaks were hypothesized. Laboratory analysis of recovered samples showed no contamination. No samples were collected from the highly contaminated lower zones to preclude contamination of people and equipment during recovery.

#### **B.6.2.1 Interpretation of Results Measurements**

Each of the cone penetrations was extended to refusal. The majority of the pushes were within the S tank farm excavation. Pushes CP-00-02, -02A and -02B were outside the farm excavation as evidenced by the limited depth to refusal (Table B.25). The base of the farm in all areas investigated is a compacted surface, likely due to extended vehicular compaction during the construction process. (Construction specifications HW-3937, indicate that the zone under the tanks was likely not mechanically compacted prior to placement of the tank bases.)

The compacted portions of the tank farm excavation provide a surface upon which tank derived fluids would spread. Evidence supporting this interpretation is the high count rate materials found in CP-03, -04 and -05 locations in the range of 12.2 to 13.7 m (40 to 45 ft) bgs. The full volume of impacted sediments could not be determined due to the limited depth that could be interrogated. It is probable that contamination resulting from an overfill would also extend beneath the tank.

Two push locations, CP-04 and CP-05, where a high gamma signature was found above the base of the excavation at 9.2 and 9.1 m (30.25 and 29.75 ft) bgs, respectively, support the hypothesis that this S tank farm contamination is due to an overfill of tank S-104. Limitations on how close to a tank wall a mechanized excavation can be performed severely impact full resolution of this leak hypothesis. Figure B.32 is a conceptualization of the extent of contamination associated with tank S-104.

#### **B.6.2.2 Estimate of Inventory Based on Measurements**

It was necessary to make a number of assumptions to estimate the possible inventory held in the vadose zone beneath tank S-104. The following outline those assumptions.

- **Extent of contamination** – The contaminants are symmetrically dispersed about the hypothesized source in a circle that is an approximately 12 m (39 ft) radius.
- **Depth of contamination** – Total thickness is 0.3 m (1 ft) based on the depth of greater than  $10^6$  pCi/g cesium concentration that is cited in GJPO (2000).
- **Concentration** – The maximum concentration reported for borehole 40-04-05 (GJPO 2000), which is  $2.0 \times 10^6$  pCi/g
- **Soil Density** – Throughout subject area is assumed to be 1.8 g/cc.

**Table B.25. Summary of Data from Gamma Cone Penetrometers in the S Tank Farm**

Location/ Well #	Final Depth (ft)	Cone Datafile	Spectrum Datafile	Spectrum Depth (ft)	Counts/ sec	Sample Depth
CP-00-02 C3049	33.01	527J0001C.DAT				
CP-00-02A C3050	8.10	528J0002C.DAT	28JANB.CHN 28JANC.CHN 28JAND.CHN 28JANE.CHN 28JANF.CHN	1.05 2.05 3.85 5.35 6.85	60 60 45 45 45	
CP-00-02B C3051	15.00	528J0003C.DAT	28JANI.CHN 28JANJ.CHN 28JANK.CHN 28JANL.CHN 28JANM.CHN	1.13 2.55 4.05 5.55 6.75	45 45 45 45 45	
CP-04-03 C3052	46.35	531J0001C.DAT	31JANB.CHN 31JANC.CHN 31JAND.CHN 31JAN3.CHN	43.25 43.65 44.05 45.15	500 2,000 12,000 180,000	
CP-04-04 C3053	44.40	501F0001C.DAT	01FEBB.CHN 01FEBC.CHN 01FEBD.CHN 01FEBE.CHN 01FEBF.CHN 01FEBG.CHN	27.25 28.75 30.25 31.75 38.75 40.25	300 8,700 15,000 2,200 320 60,000	31.75-33.75 28.75-30.70
CP-04-02 C3055	47.02	502F0003C.DAT				
CP-04-11 C3056	50.74	503F0001C.DAT				
CP-04-05 C3057	43.95	503F0004C.DAT	03FEBD.CHN 03FEBE.CHN 03FEBF.CHN 03FEBG.CHN 03FEBH.CHN 03FEBI.CHN 03FEBJ.CHN 03FEBK.CHN	27.05 28.25 29.75 31.25 32.75 34.25 39.25 40.75	450 9,000 80,000 35,000 3,500 300 350 125,000	31.25-33.75
CP-02-05 C3059	39.5	507F0003C.DAT				
CP-02-02 C3060	42.9	508F0001C.DAT				

**Figure B.32. Estimated Extent of Shallow Contamination Zone Down  
to 50 ft (16 m) Below Ground Surface Near Tank S-104**

Insert Figure B.32.

Based on this gross calculation, approximately 500 curies of cesium-137 would be included in the plume. The total inventory of cesium-137 calculated by MACTEC-ERS (GJPO 2000) is about 10 curies. Neither of these inventory estimates supports the reported 91,000 L (24,000 gal) leak (Hanlon 2001). Based on Jones et al. (2000) the cesium-137 inventory that would result from the reported 91,000 L (24,000 gal) loss would be approximately  $1.14 \times 10^4$  Ci.

### **B.6.3 SOIL WATER CHEMISTRY MEASUREMENTS**

Soil water chemistry measurements were not taken during the S tank farm shallow soils investigation.

### **B.6.4 CHEMICAL INTERACTIONS**

Chemical interactions were not analyzed during the S tank farm shallow soils investigation.

### **B.6.5 GROUNDWATER MEASUREMENTS**

Groundwater measurements were not applicable to the S tank farm shallow soils investigation.



## B.7.0 REFERENCES

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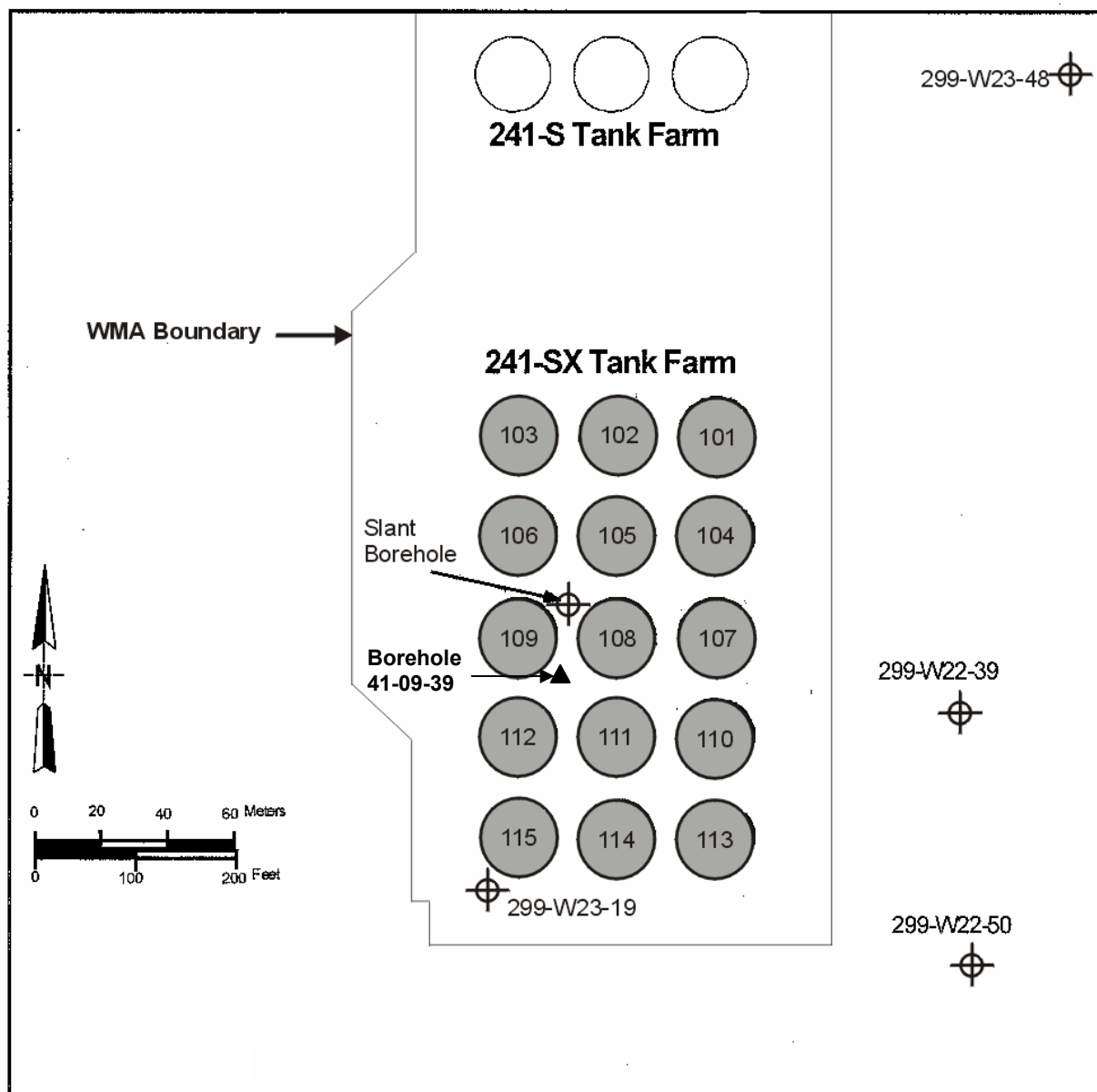
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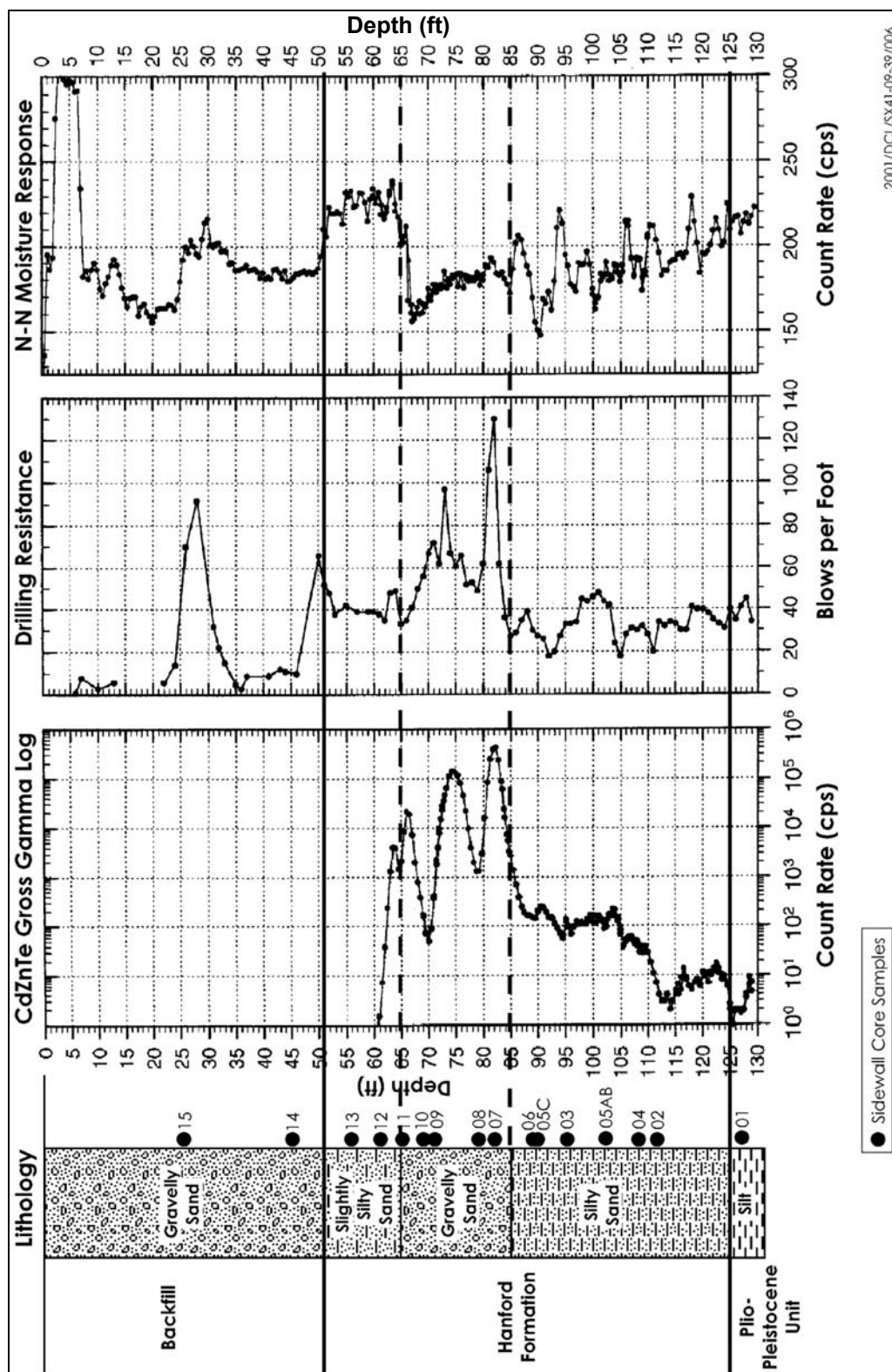
Serne, R. J., H. T. Schaef, G. V. Last, D. C. Lanigan, C. W. Lindenmeier, C. C. Ainsworth, R. E. Clayton, V. L. LeGore, M. J. O'Hara, C. F. Brown, R. D. Orr, I. V. Kutnyakov, T. C. Wilson, K. B. Wagnon, B. A. Williams, and D. B. Burke, 2001d, *Geologic and Geochemical Data Collected from Vadose Zone Sediments from Slant Borehole [SX-108] in the S/SX Waste Management Area and Preliminary Interpretations*, PNNL-2001-4, Pacific Northwest National Laboratory, Richland, Washington.

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**Figure B.1. Locations of Boreholes Sampled in Waste Management Area S-SX Characterization Studies**

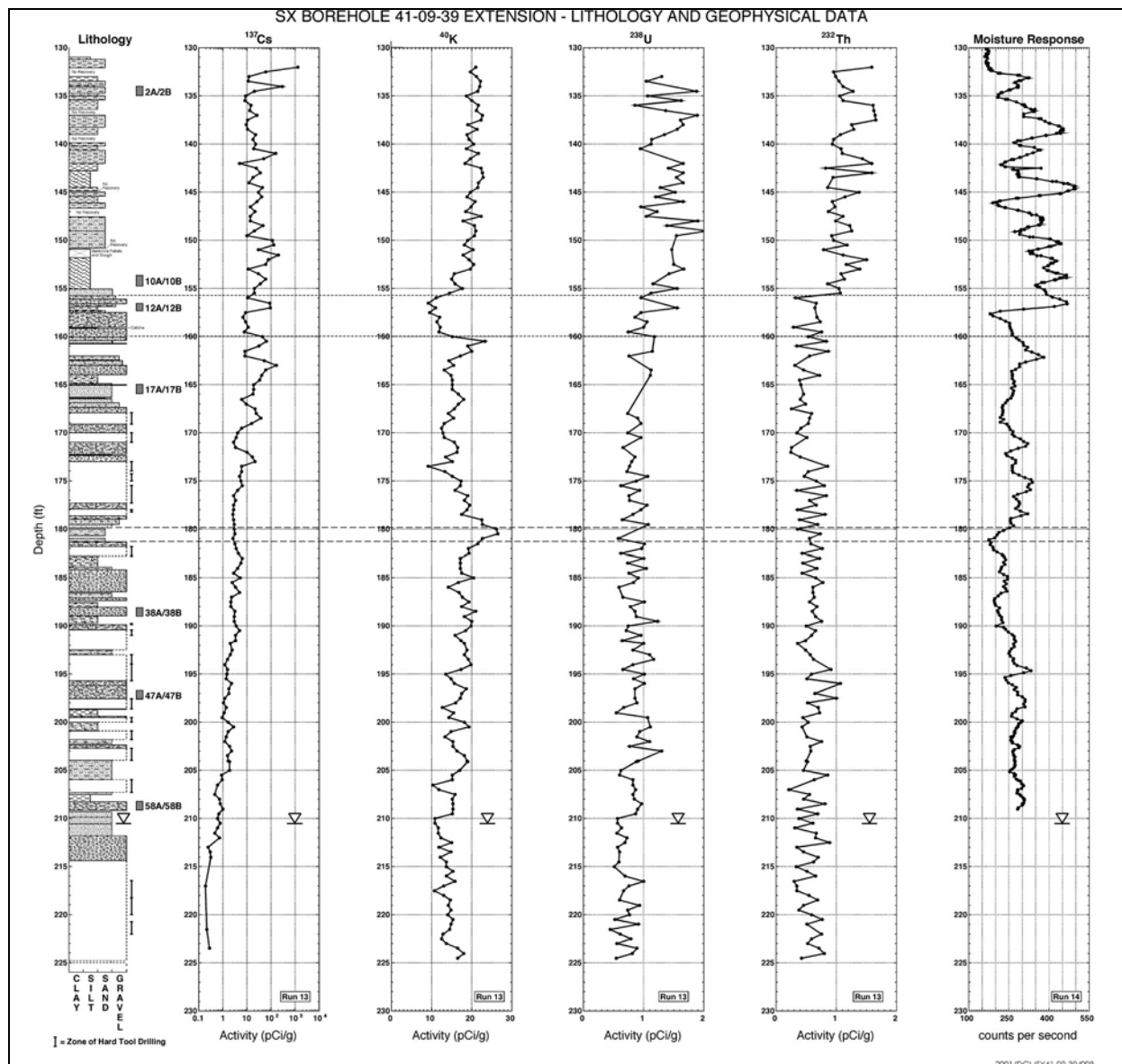


**Figure B.2. Gamma-Ray, Drilling Resistance, and Moisture Logs  
for the Upper Portion of Borehole 41-09-39**

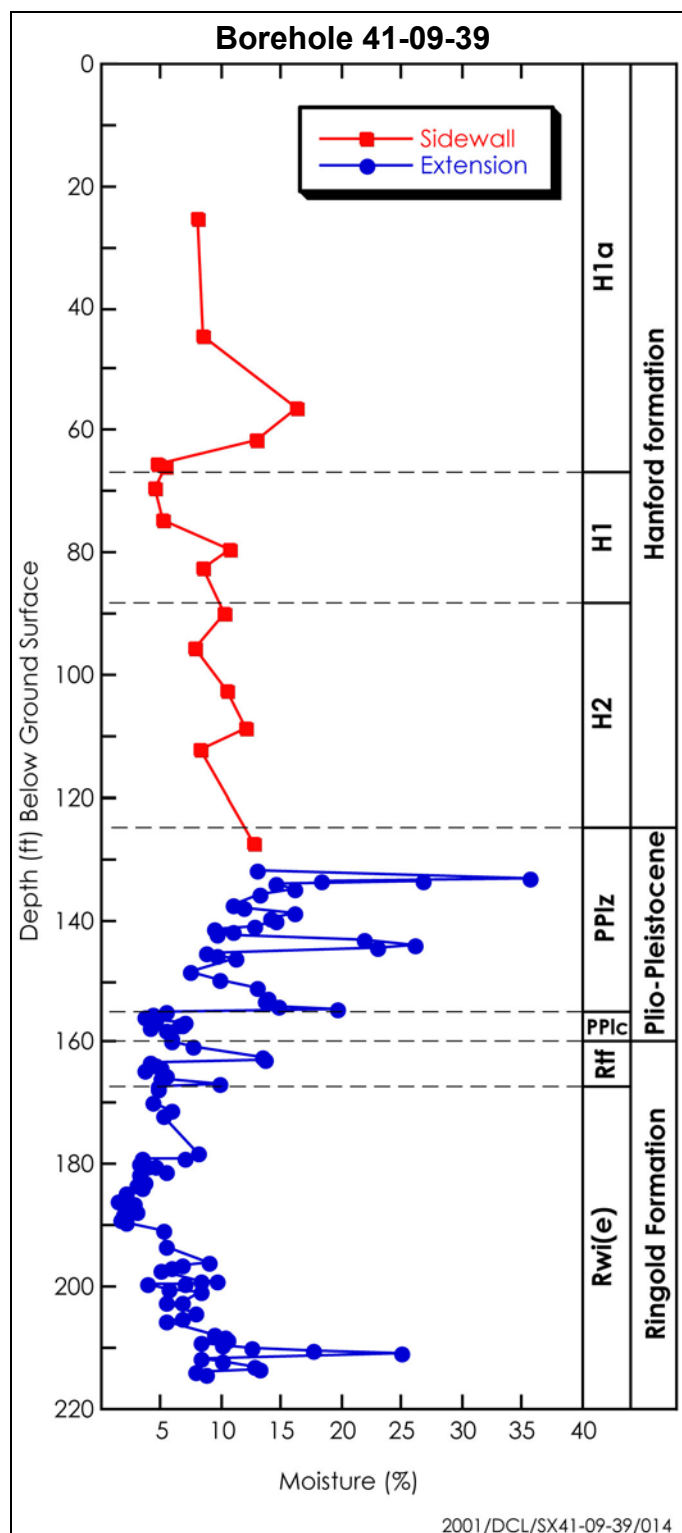


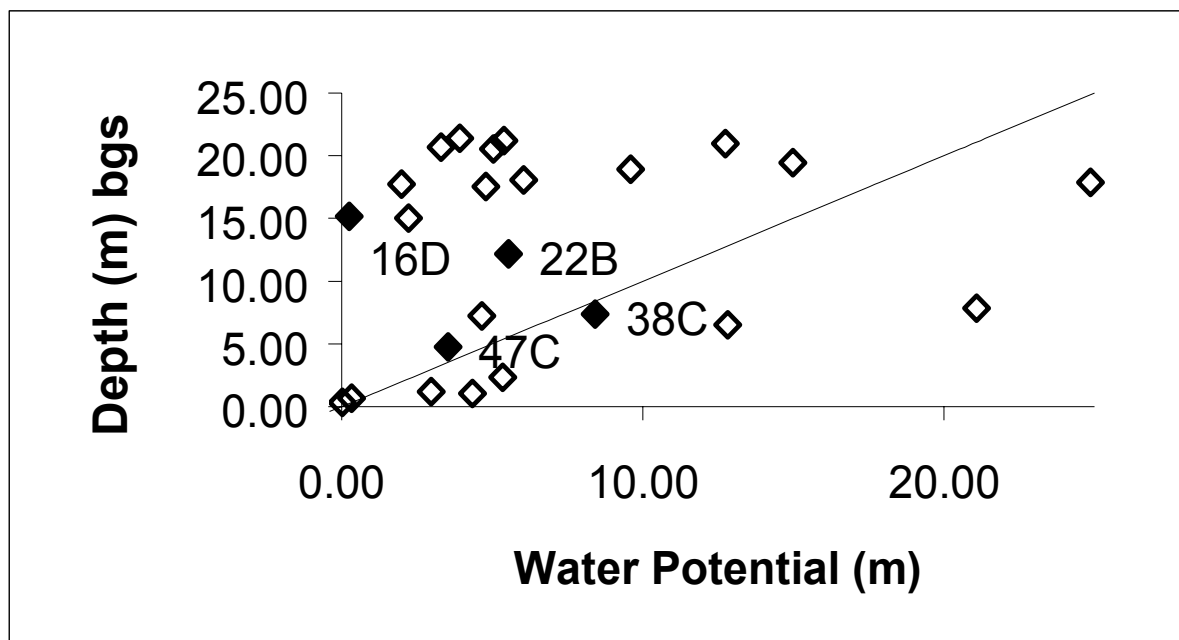
Source: MACTEC-ERS 1997.

**Figure B.3. Detailed Lithology and Analytical Values of Split-Spoon Samples from the Lower Portion of Borehole 41-09-39**

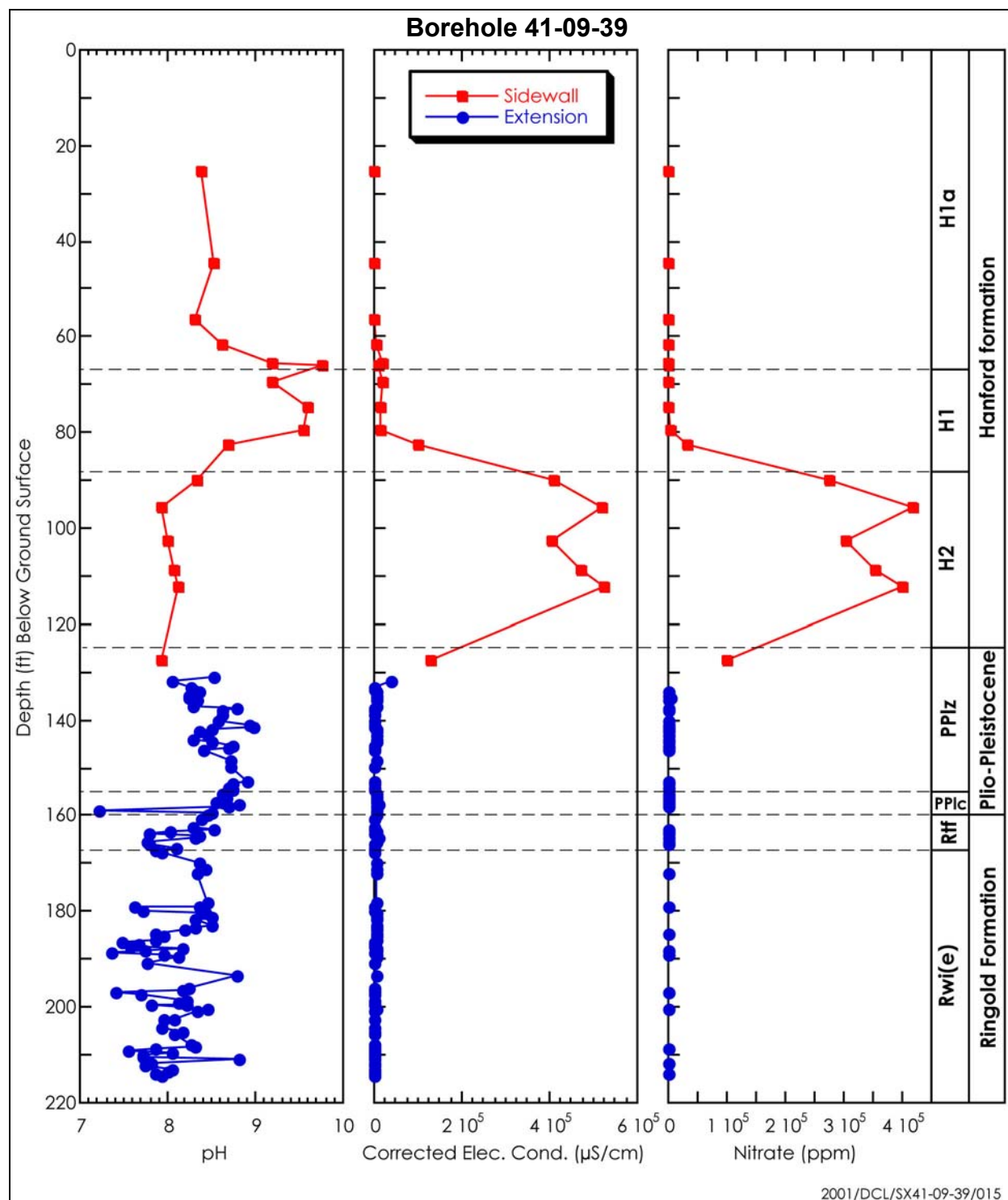


**Figure B.4. Moisture Content (wt%) versus Depth for Vadose Sediments from Borehole 41-09-39**



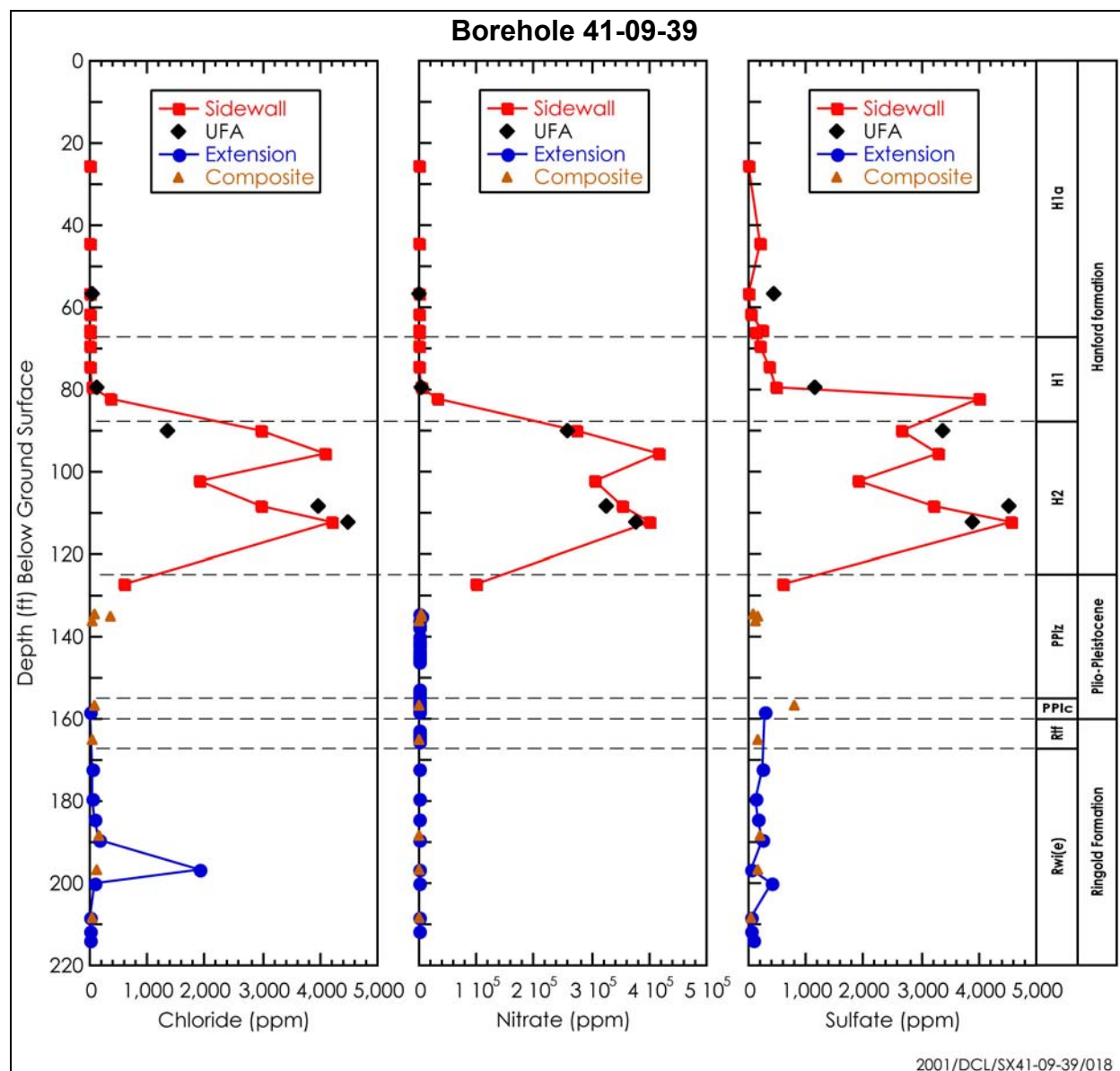
**Figure B.5. Soil Suction Profile for Samples Taken from Borehole 41-09-39**

**Figure B.6. Concentrations of pH, Electrical Conductivity, and Nitrate in Dilution-Corrected Water Extract**





**Figure B.7. Dilution-Corrected 1:1 Sediment to Water Extract Anions and Actual Porewater Anion Concentrations versus Lithology and Depth**



**Figure B.8. Dilution-Corrected Cation Concentrations at Borehole 41-09-39 in 1:1 Sediment to Water Extracts**

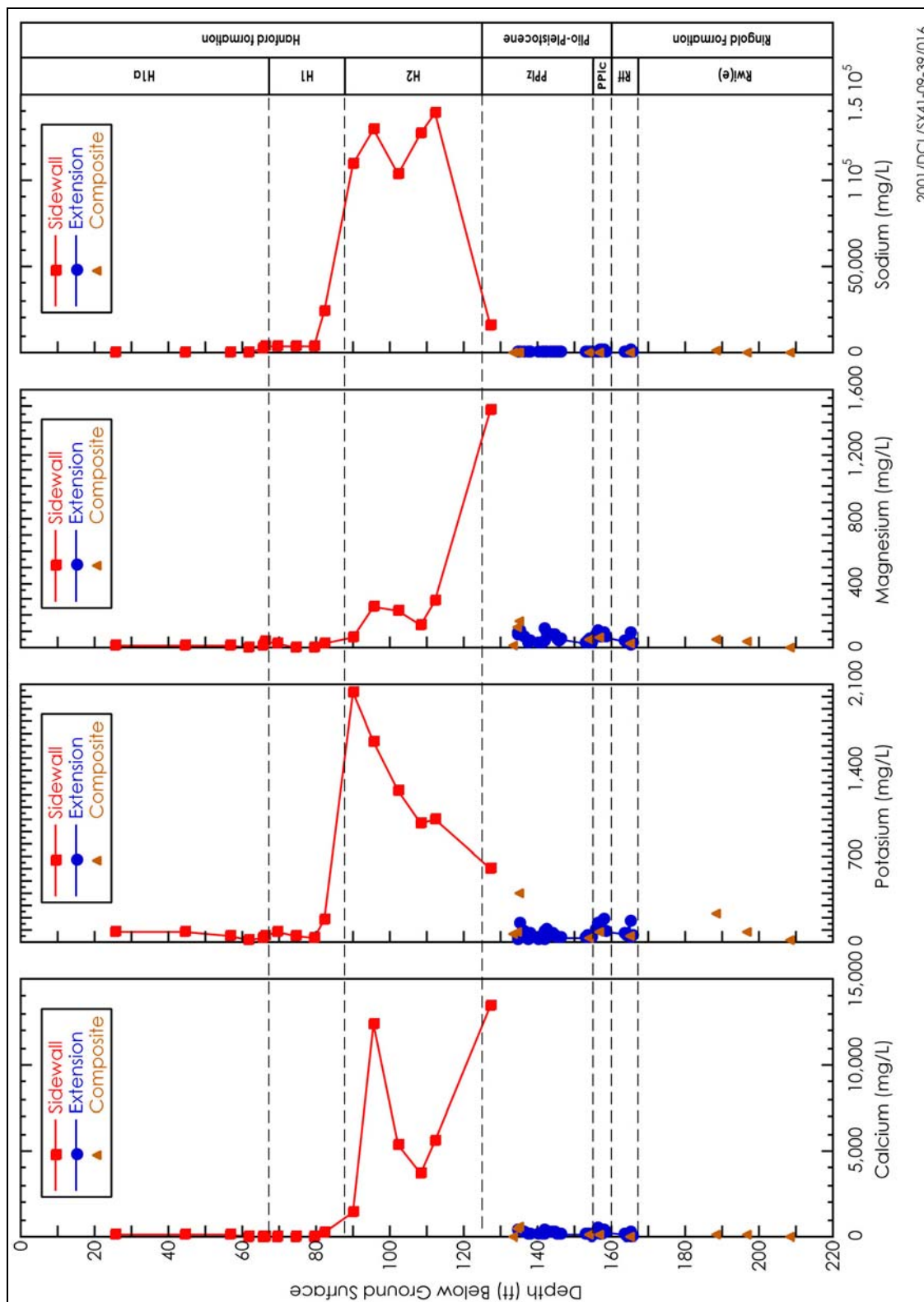
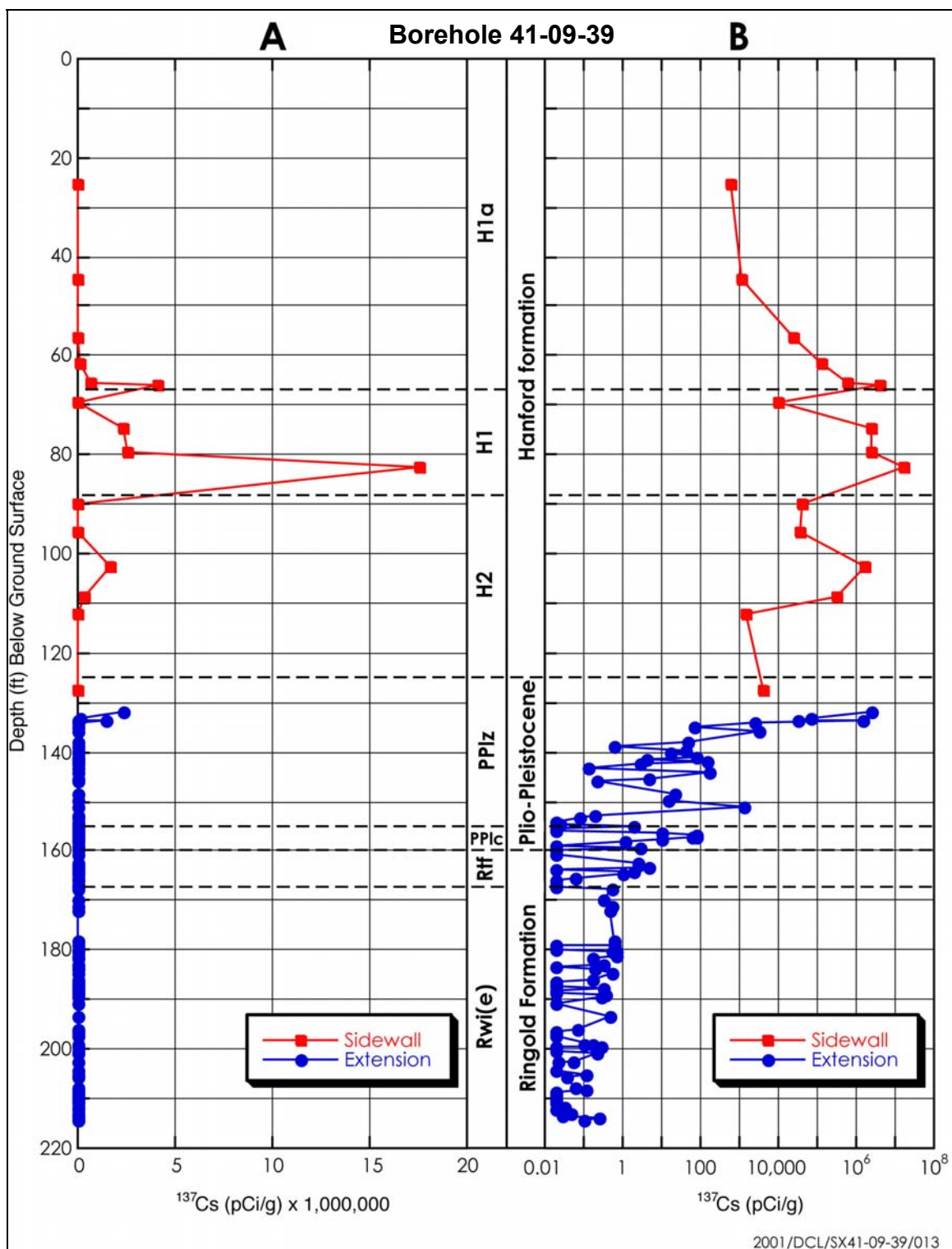
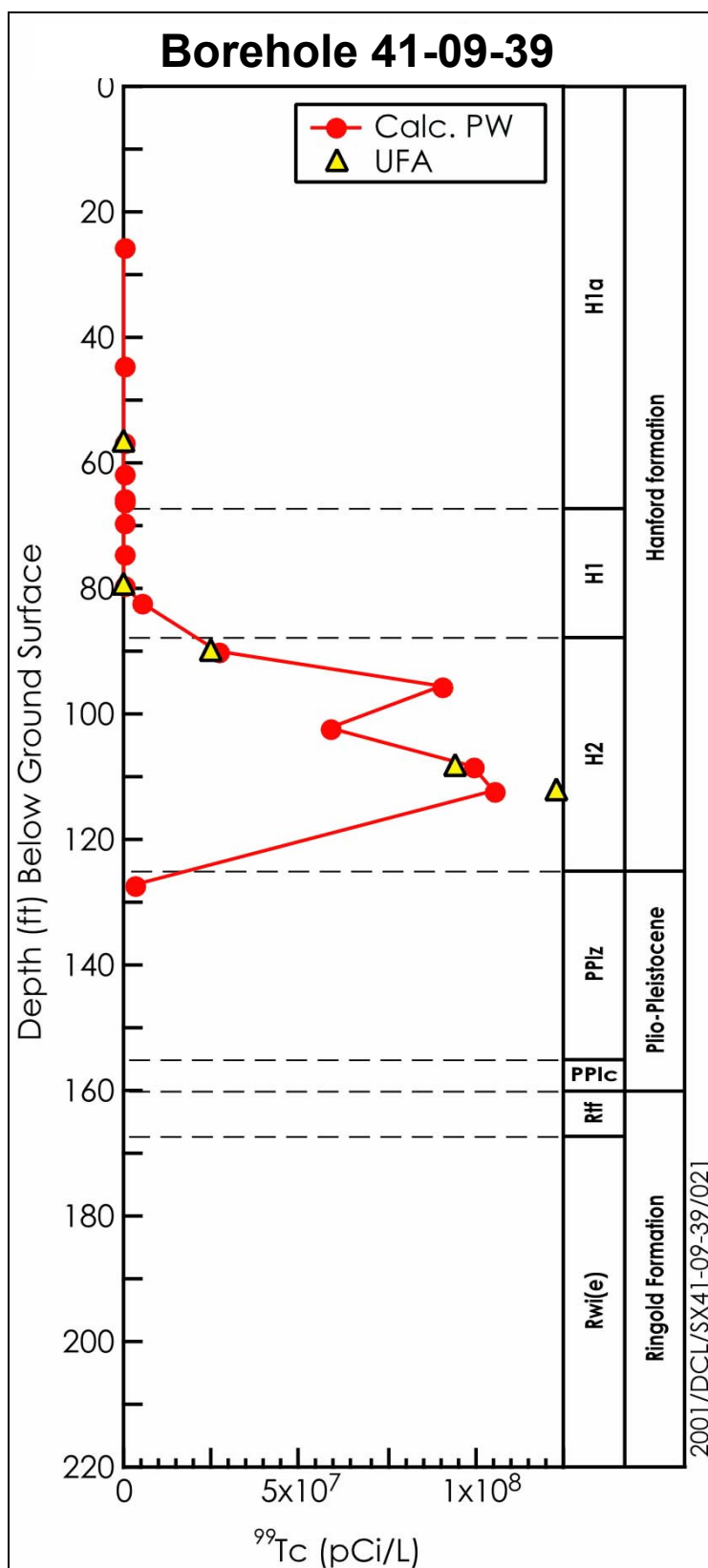


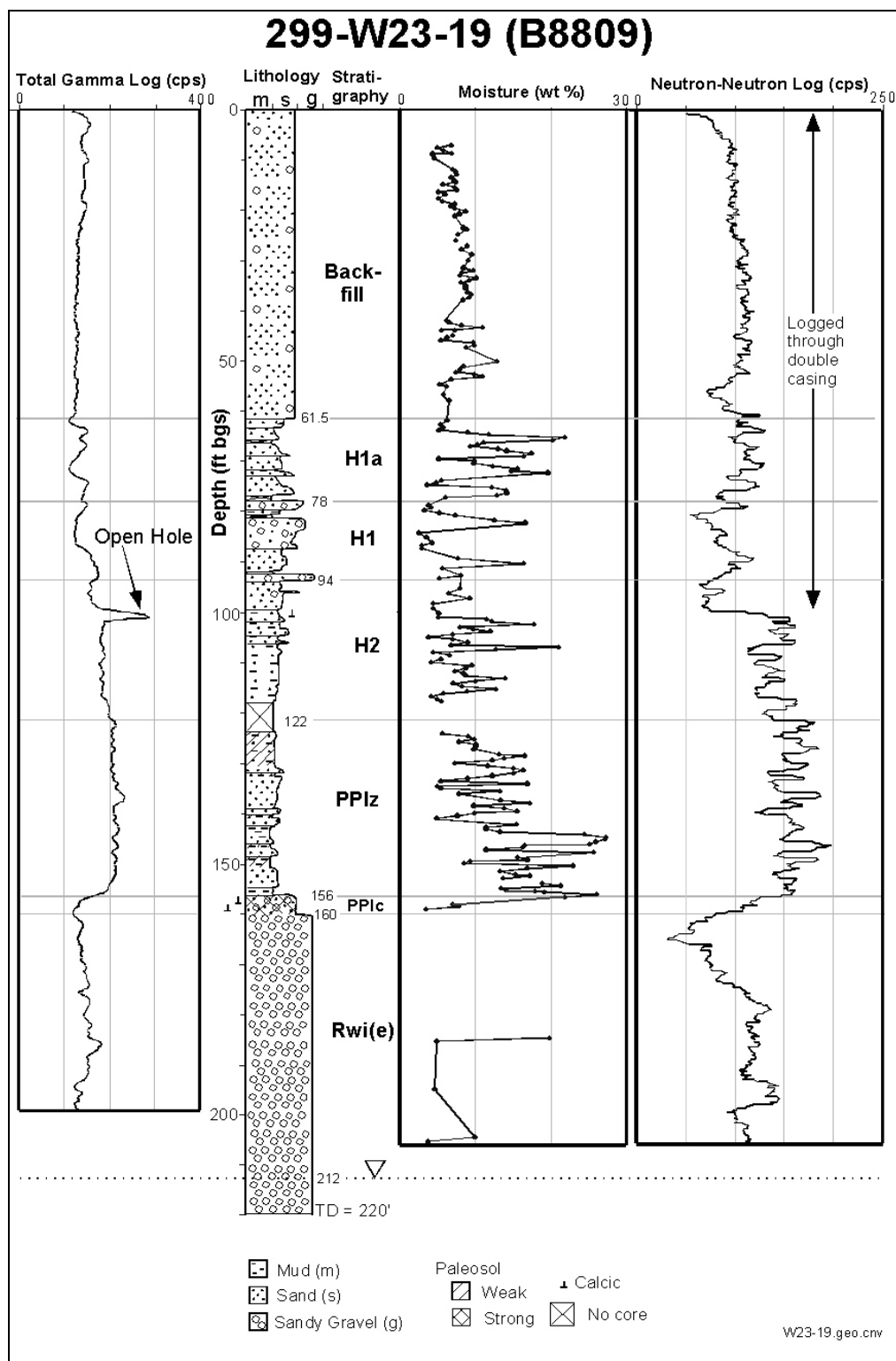
Figure B.9. Cesium-137 Activity in Sediment versus Lithology and Depth

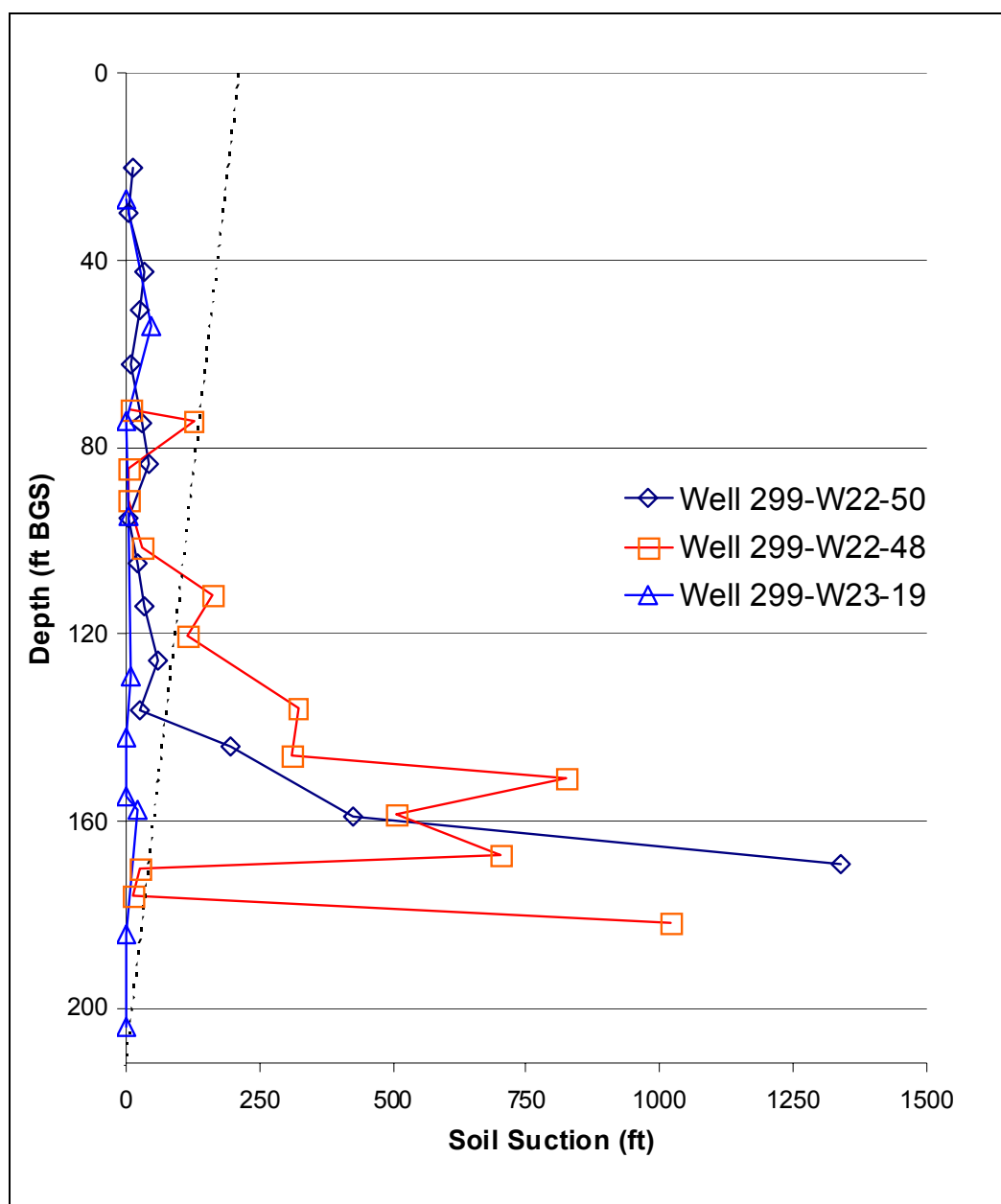


Note: A shows linear scale and B shows log scale.

**Figure B.10. Technetium-99 Activity in Porewater in Borehole 41-09-39**

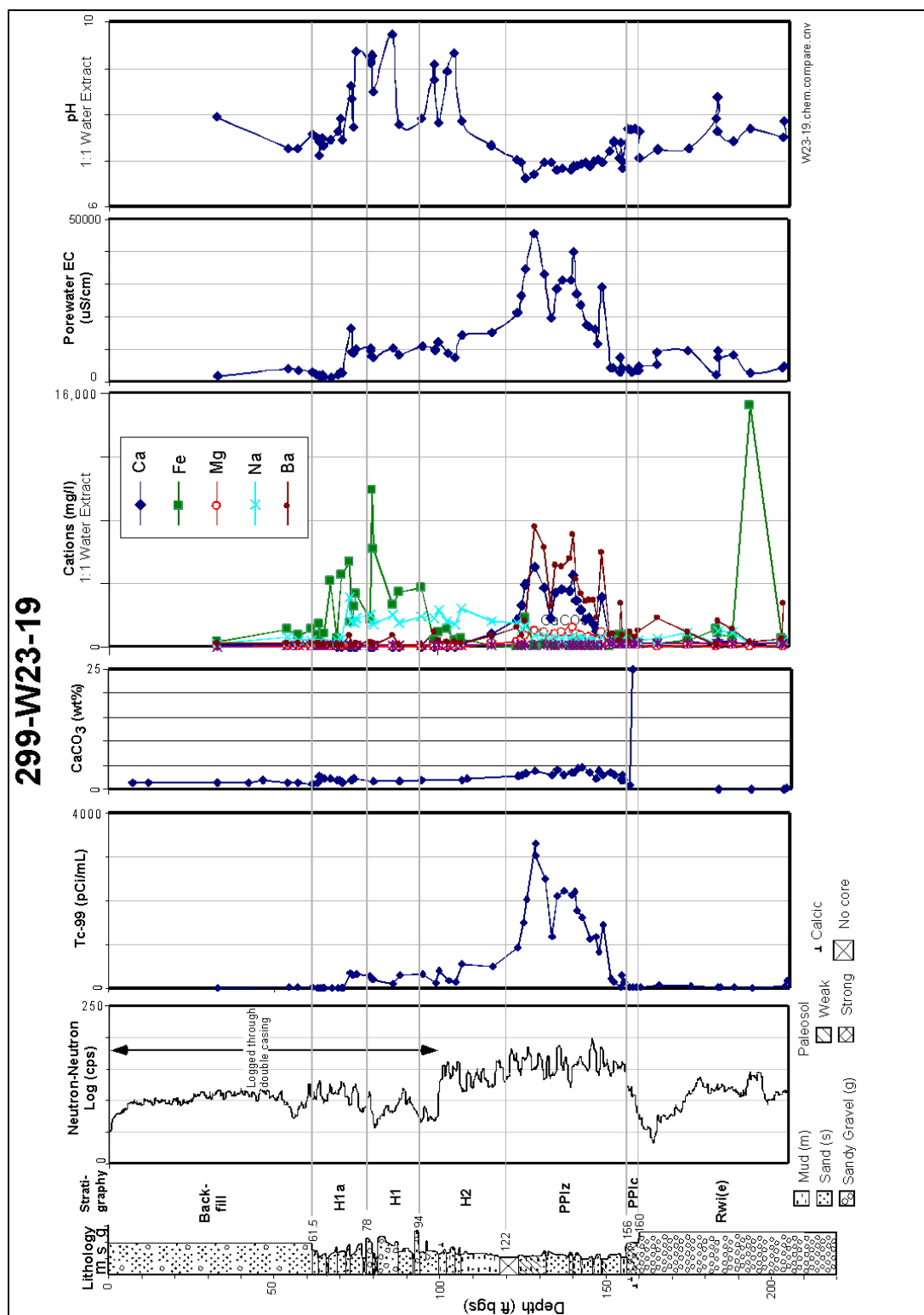
**Figure B.11. Borehole 299-W23-19 Lithology, Stratigraphy, and Moisture Content (wt%) Distribution as a Function of Depth**



**Figure B.12. Soil Suction Profiles for Borehole 299-W23-19**

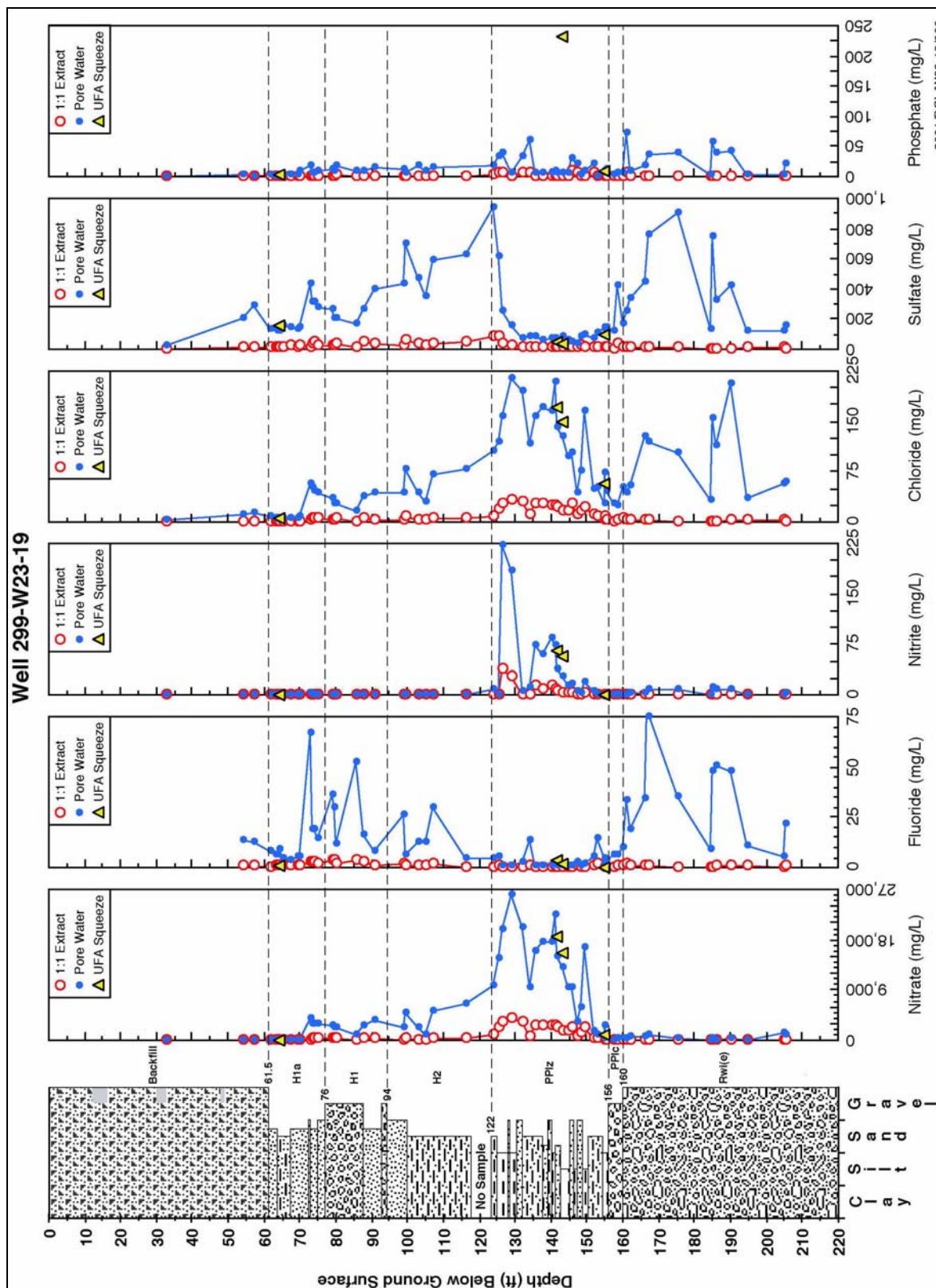
Note: Dashed line is the equilibrium soil suction line. Drainage occurs only for values to left of the equilibrium line.

**Figure B.13. Calculated and Actual Porewater pH and Electrical Conductivity Values for Borehole 299-W23-19 Sediments**



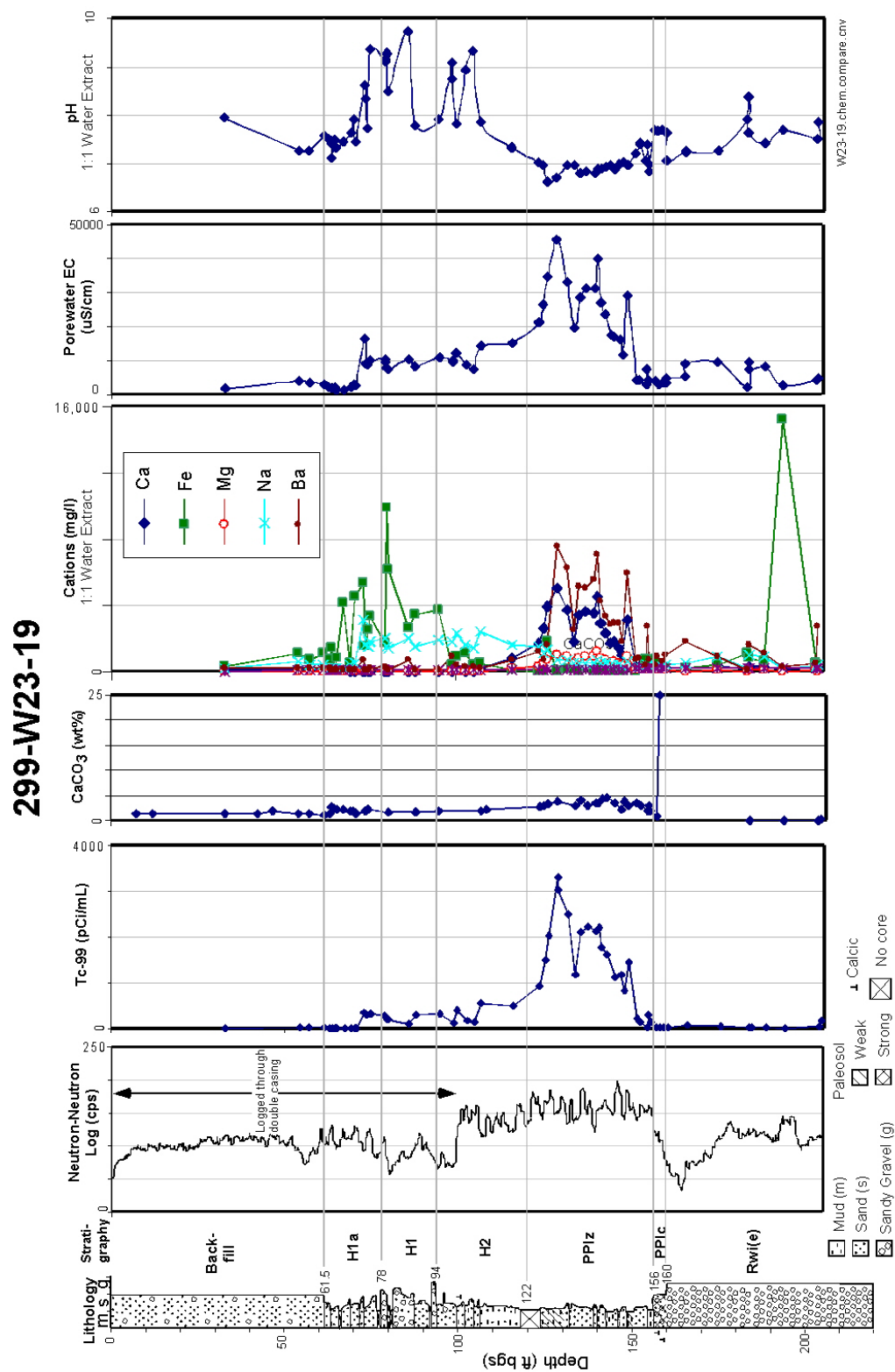


**Figure B.14. Anions Calculated and Actual Porewaters  
for Borehole 299-W23-19 Sediments**





**Figure B.15. Cations Calculated and Actual Porewaters for Borehole 299-W23-19 Sediments**



**Figure B.16. Trace Metals Calculated from Sediment Water Extracts and Actual Porewaters for 299-W23-19 Sediment**

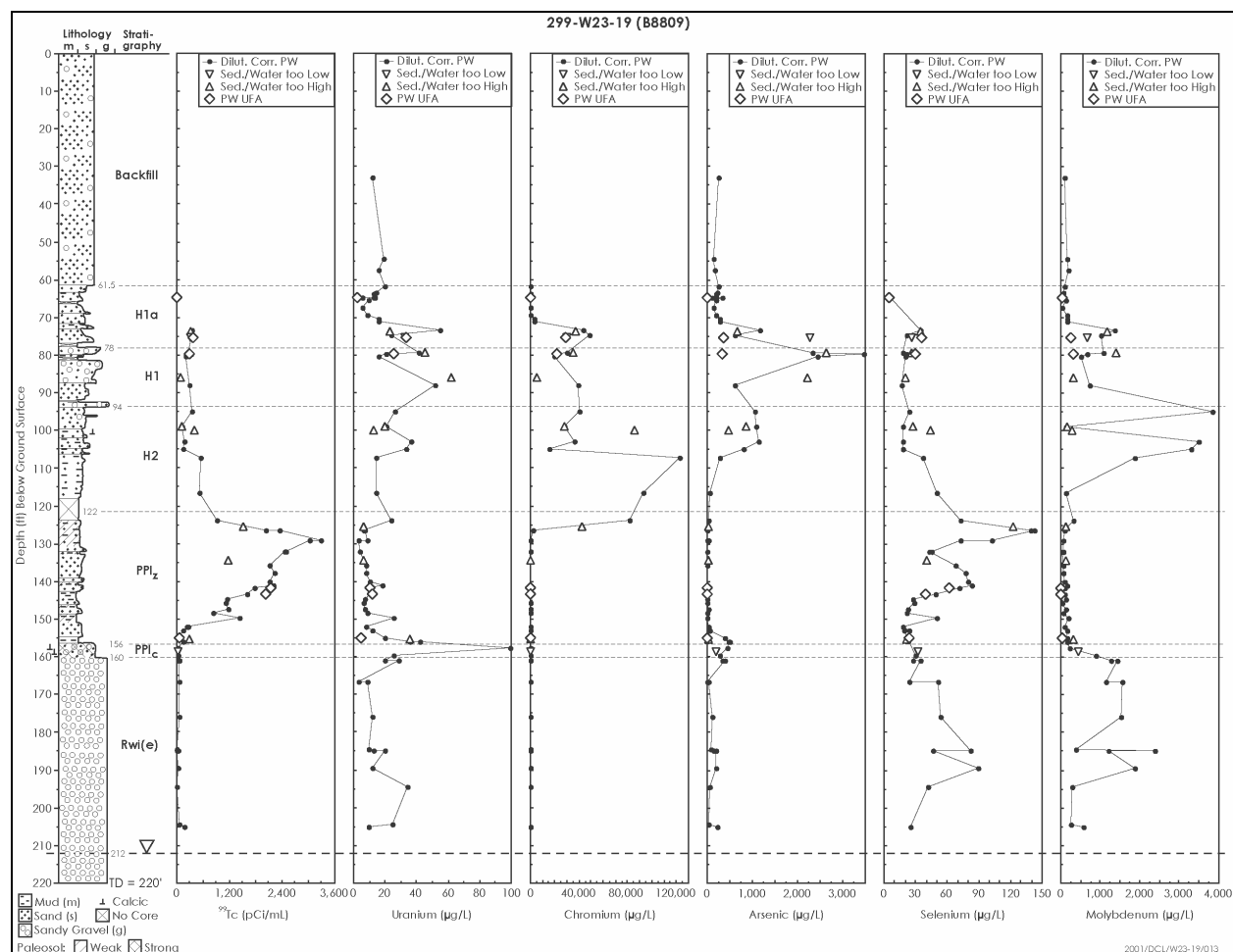
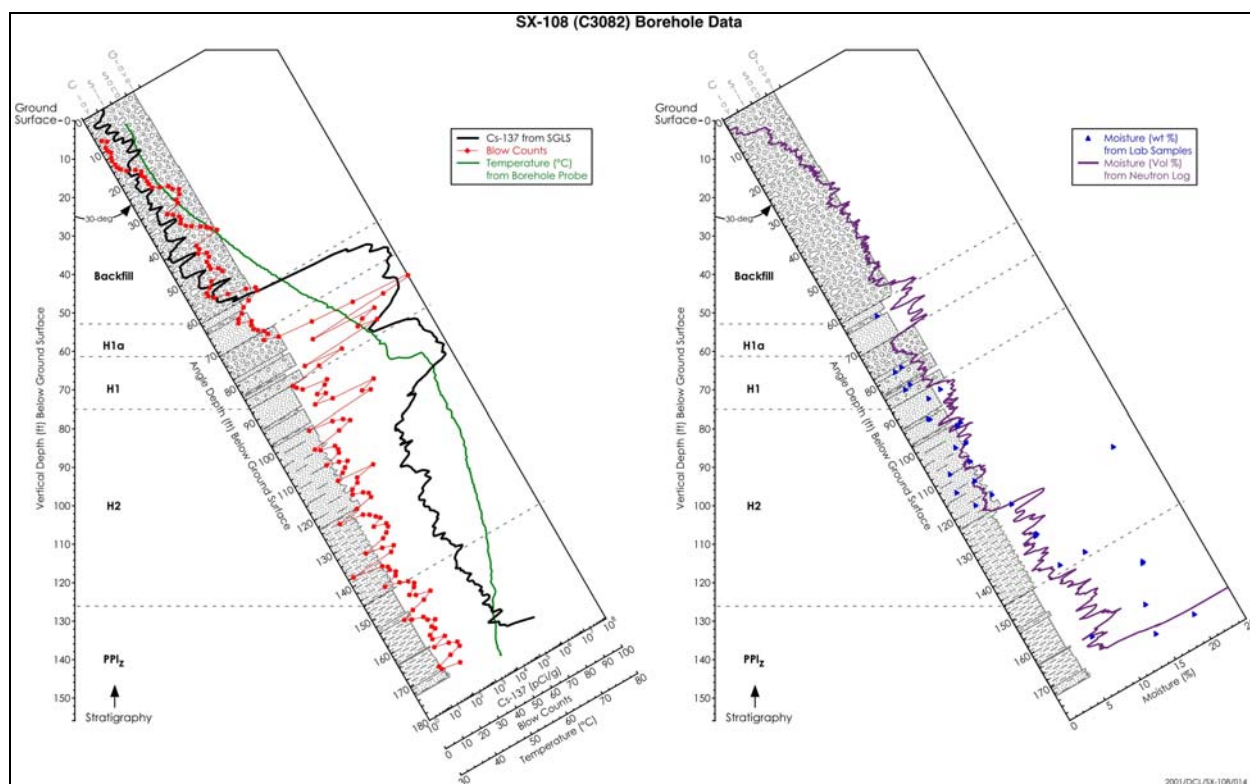
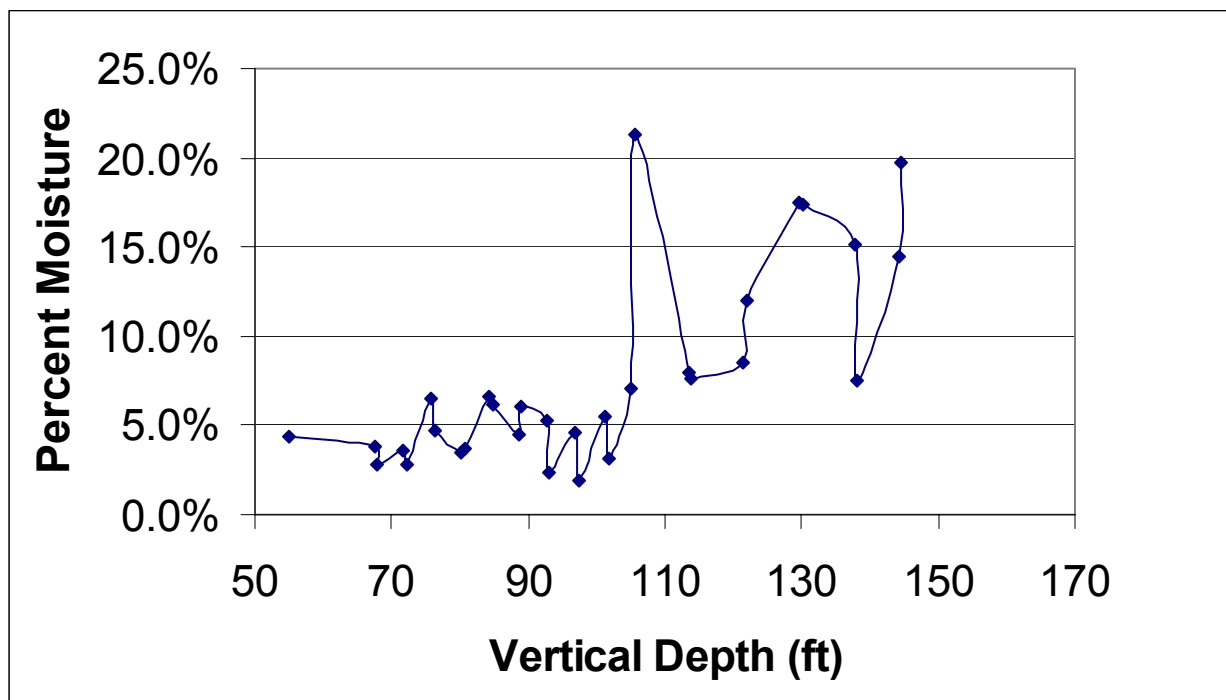


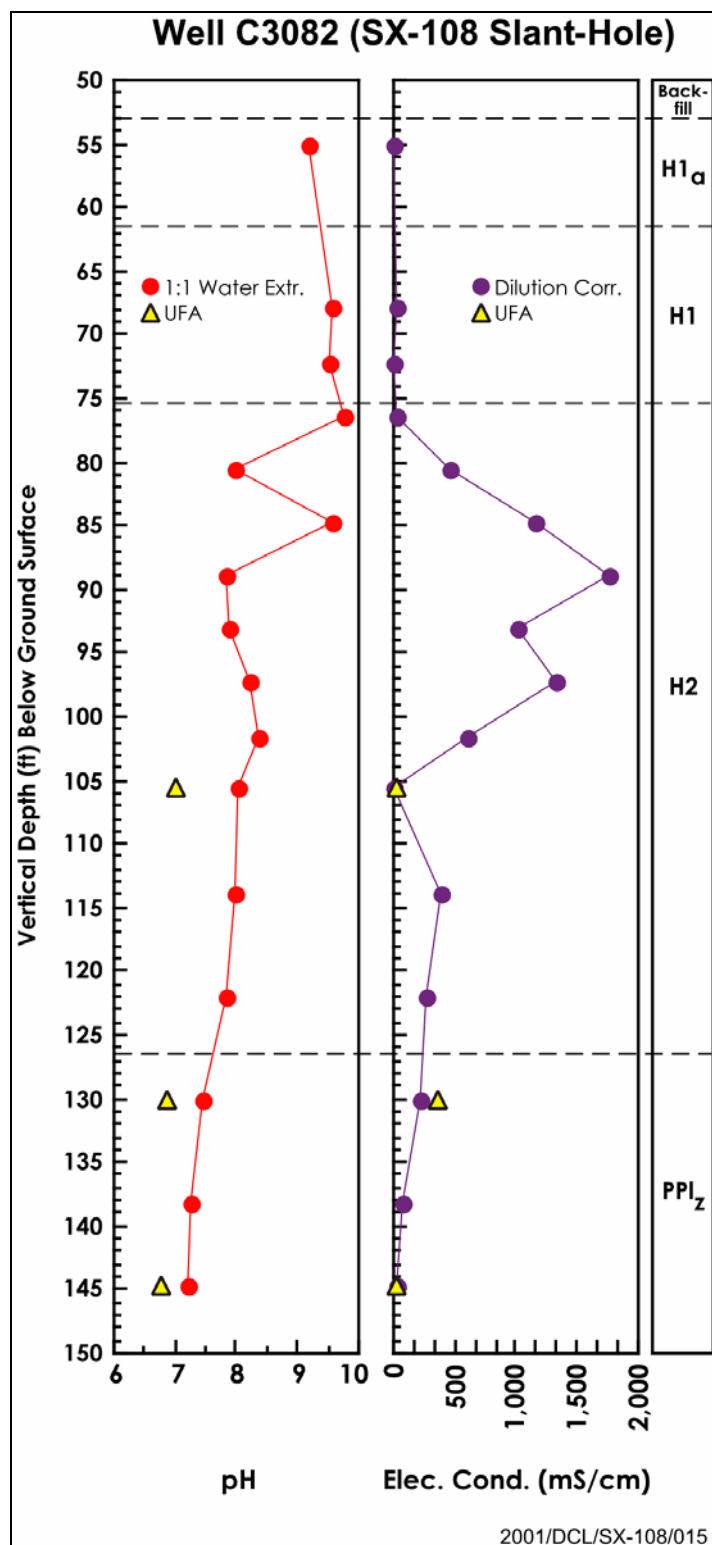
Figure B.17. Geophysics Logging Graph for SX-108 Slant Borehole



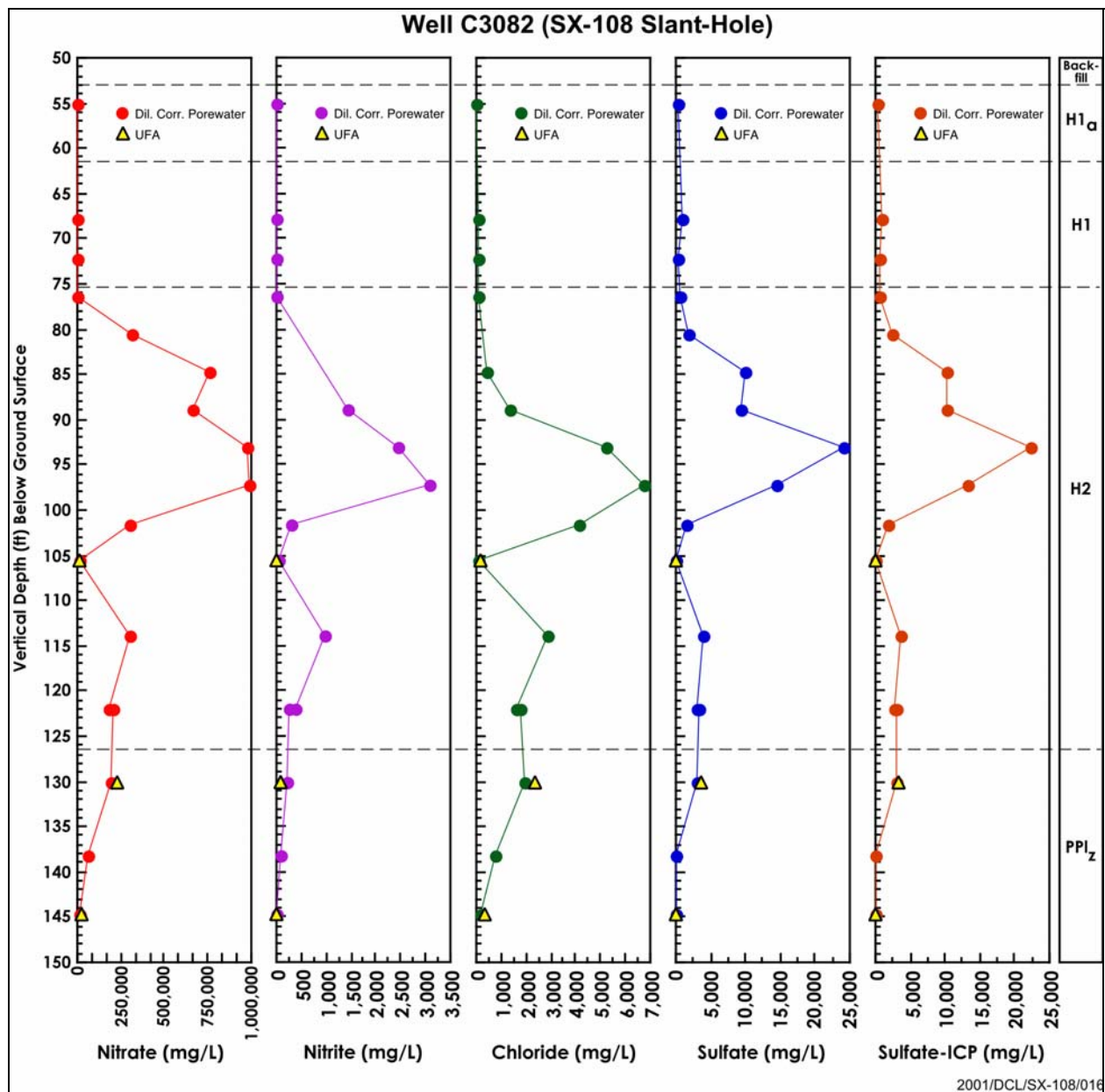
**Figure B.18. Moisture Content (wt%) in Vadose Zone  
Sediment Profile at SX-108 Slant Borehole**



**Figure B.19. SX-108 Slant Borehole pH and Electrical Conductivity Profiles with Depth**



**Figure B.20. Anions Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**



**Figure B.21. Cations Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**

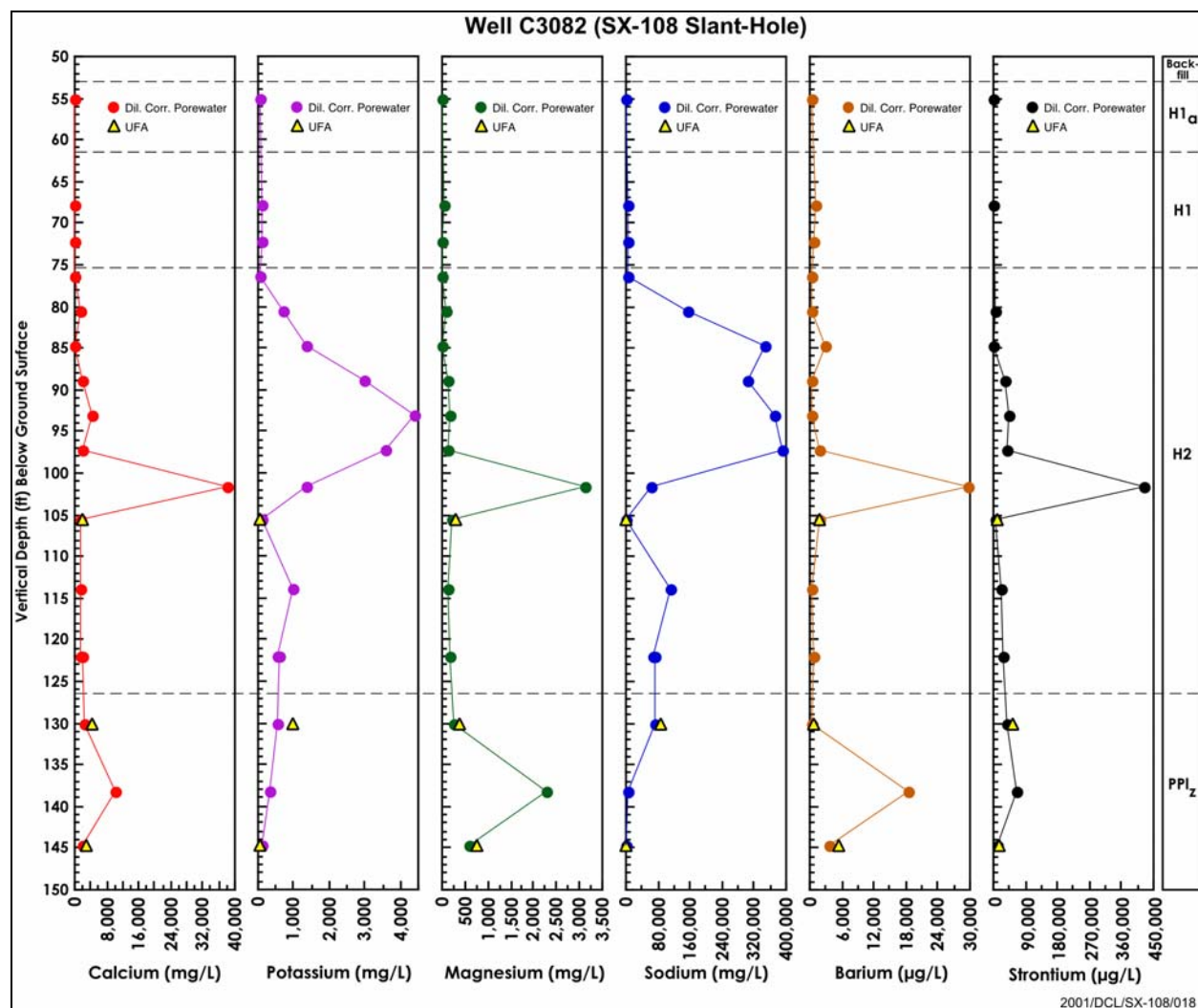
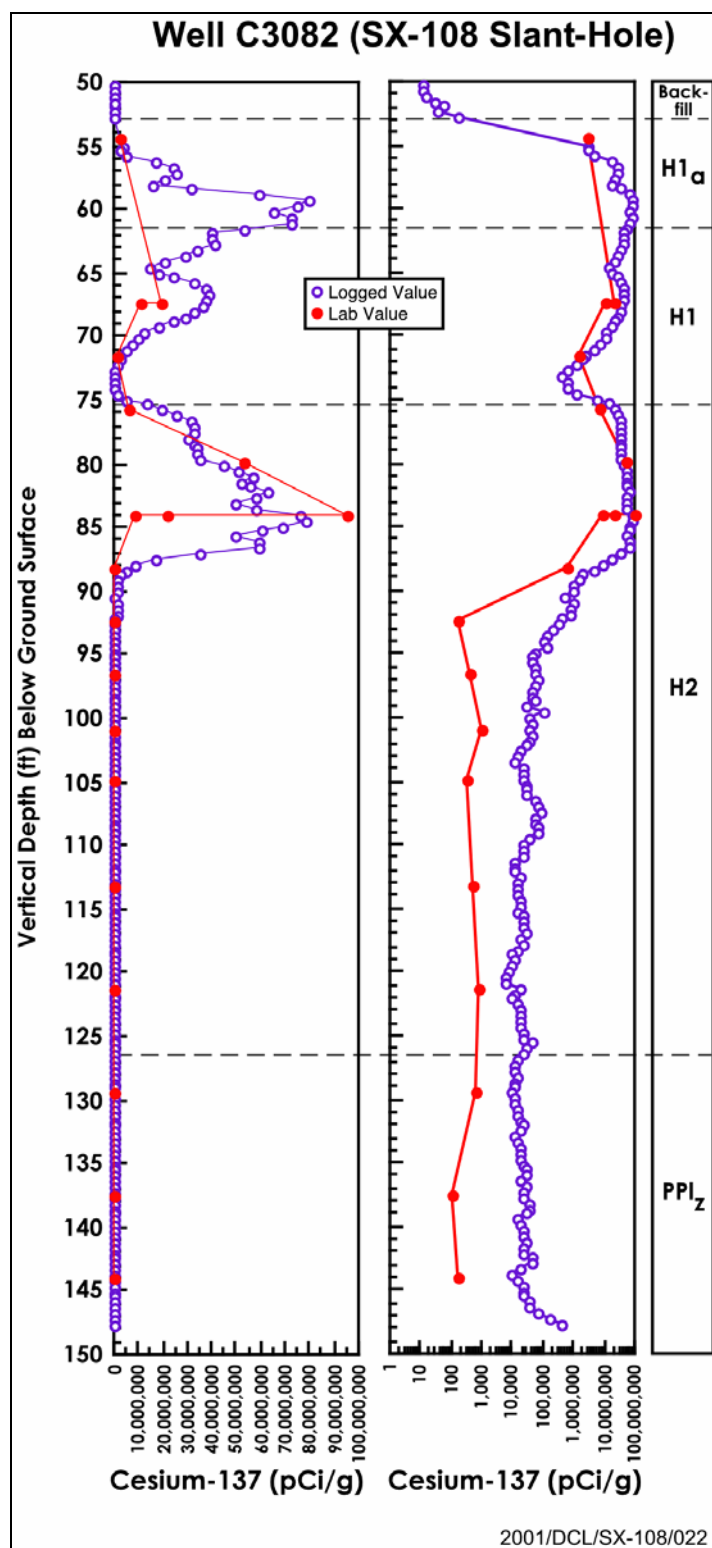
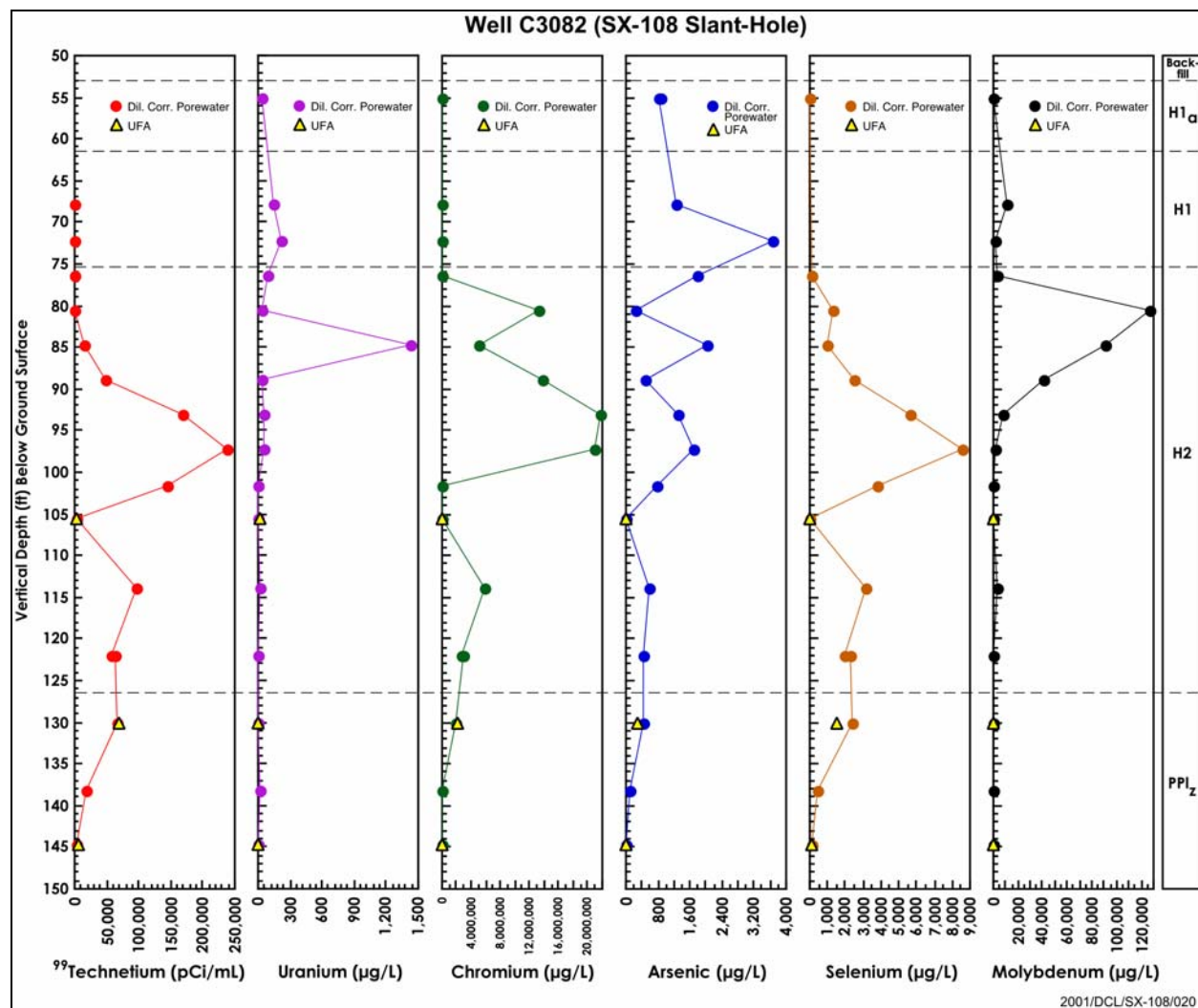


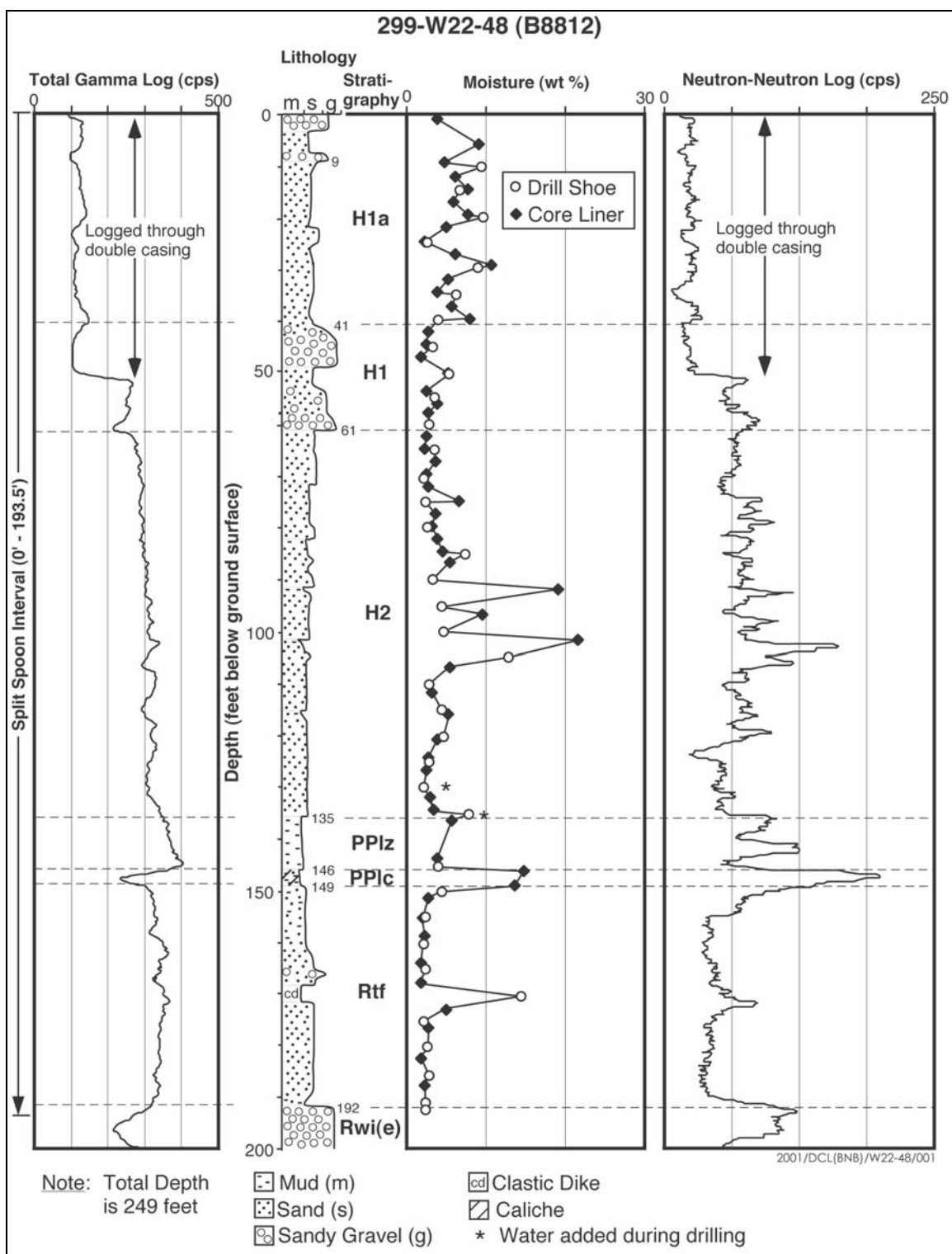
Figure B.22. Cesium-137 in Vadose Sediments at the SX-108 Slant Borehole

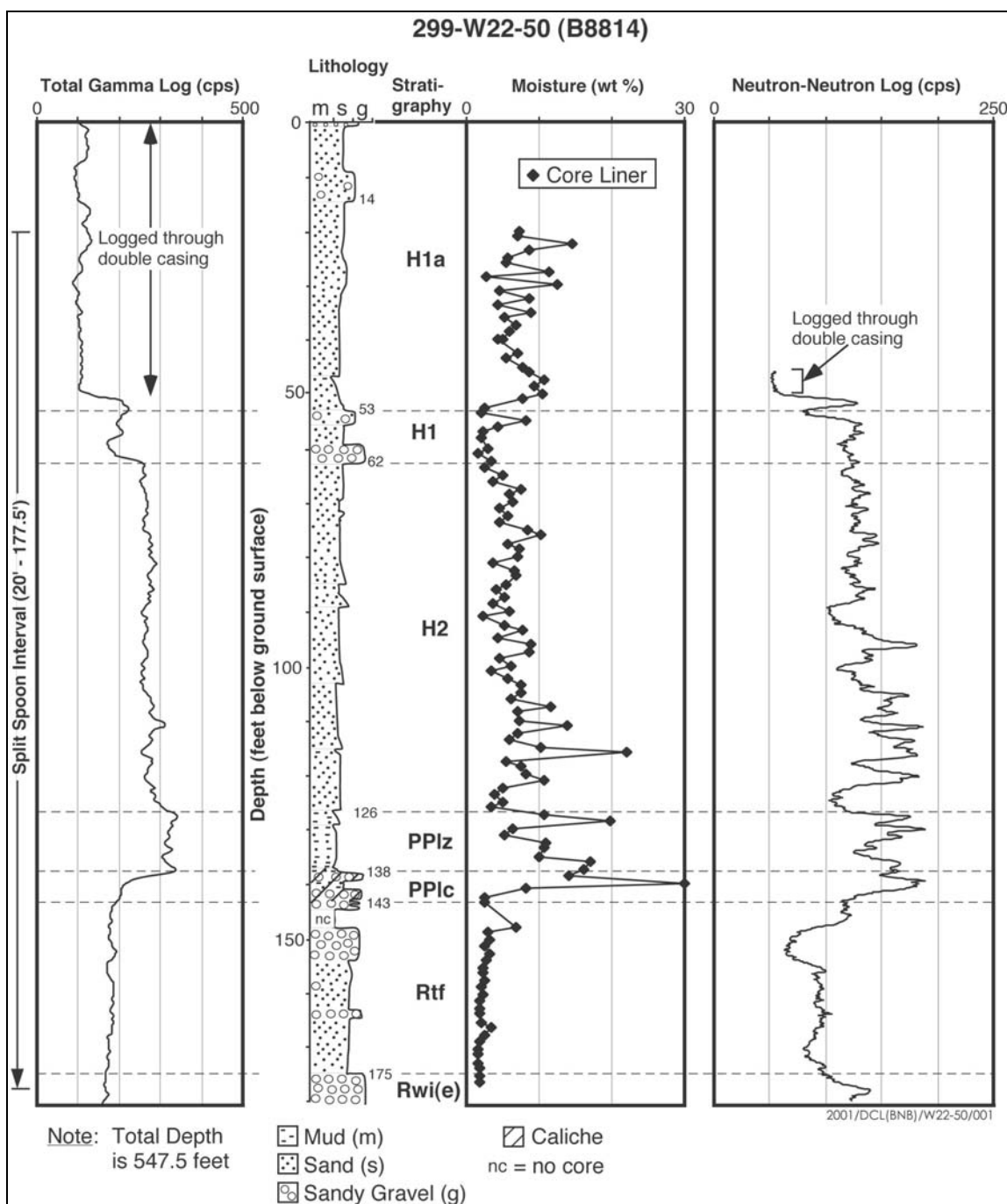




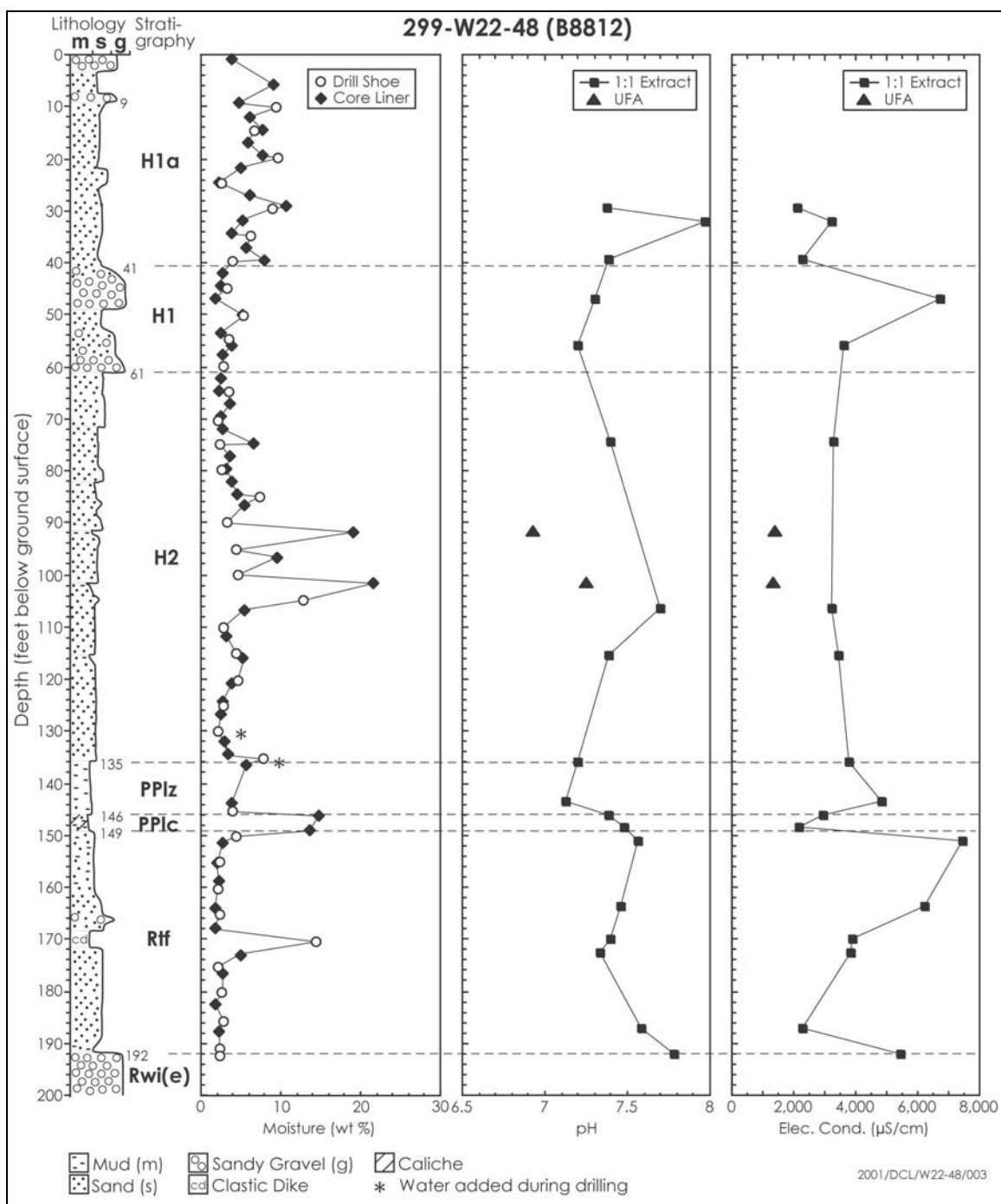
**Figure B.23. Trace Metals Calculated and Actual Porewaters  
for SX-108 Slant Borehole Sediments**



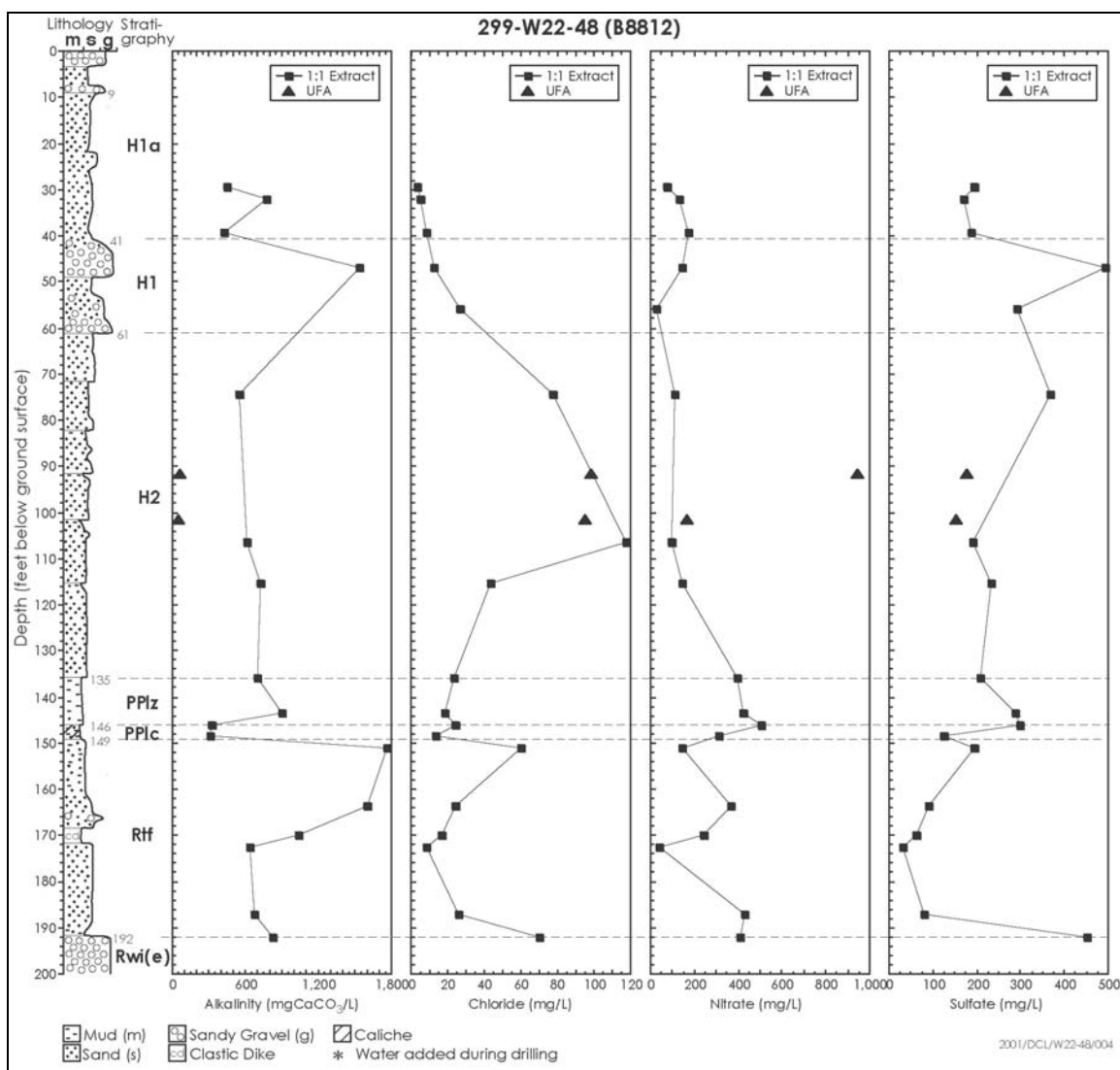
**Figure B.24. Vadose Zone Stratigraphy for Borehole 299-W22-48**

**Figure B.25. Vadose Zone Stratigraphy for Borehole 299-W22-50**

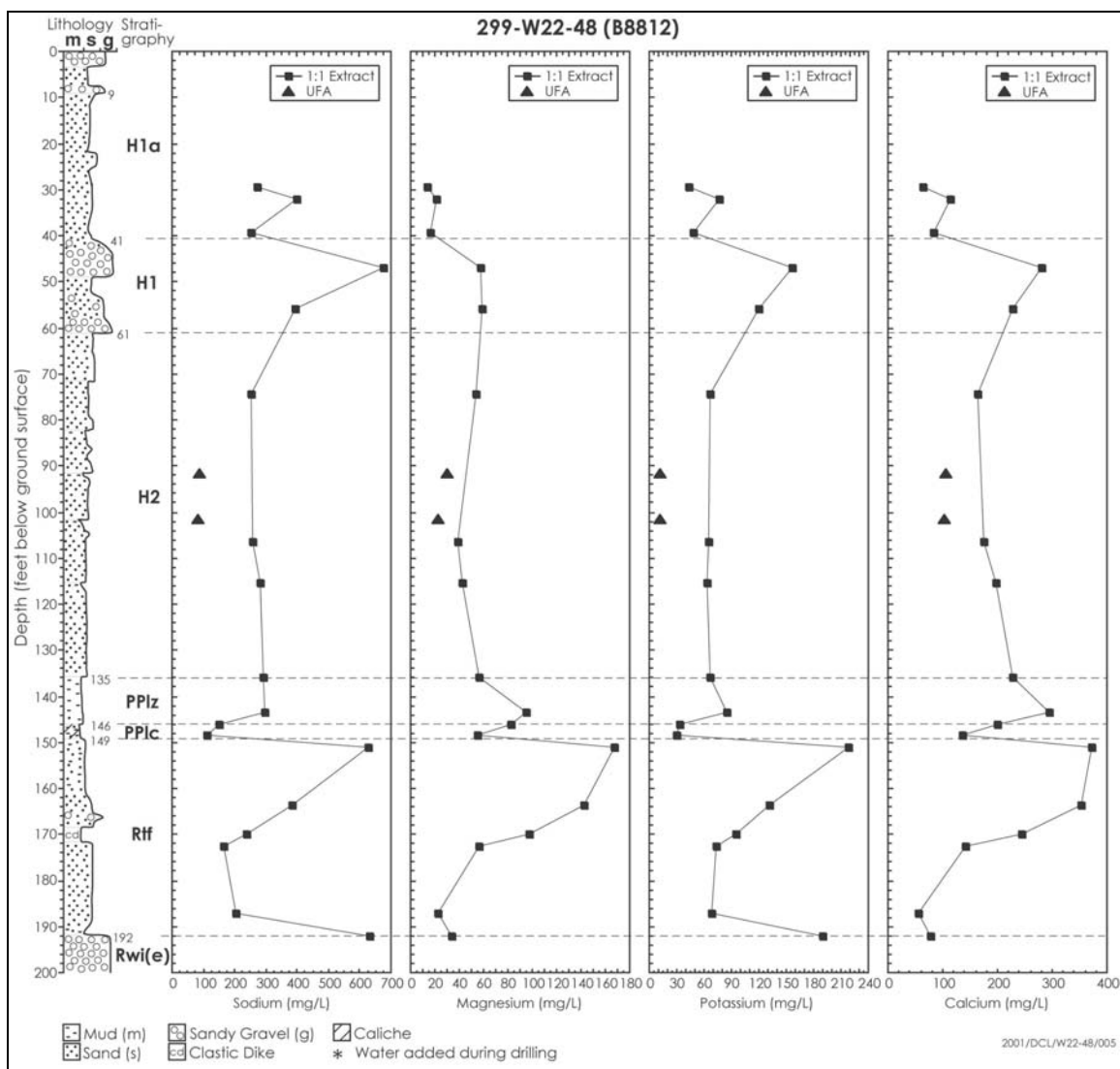
**Figure B.26. Moisture Content (wt%) of Sediment, pH and Dilution-Corrected Electrical Conductivity of Water Extract and Actual Porewater versus Depth and Stratigraphy for Borehole 299-W22-48**



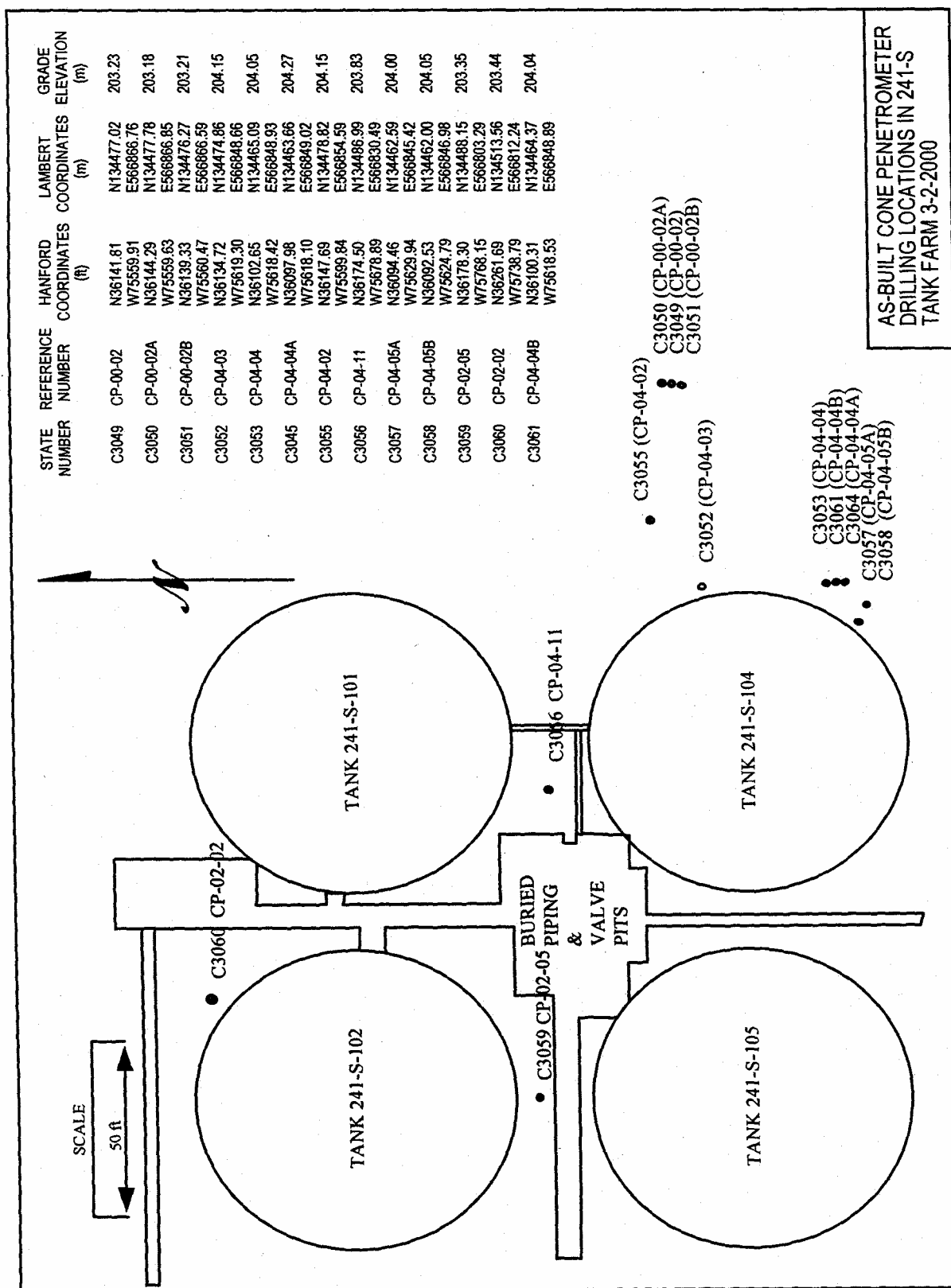
**Figure B.27. Dilution-Corrected Anion Content of Water Extracts and Anion Concentration in Actual Porewater versus Depth and Stratigraphy for Borehole 299-W22-48**



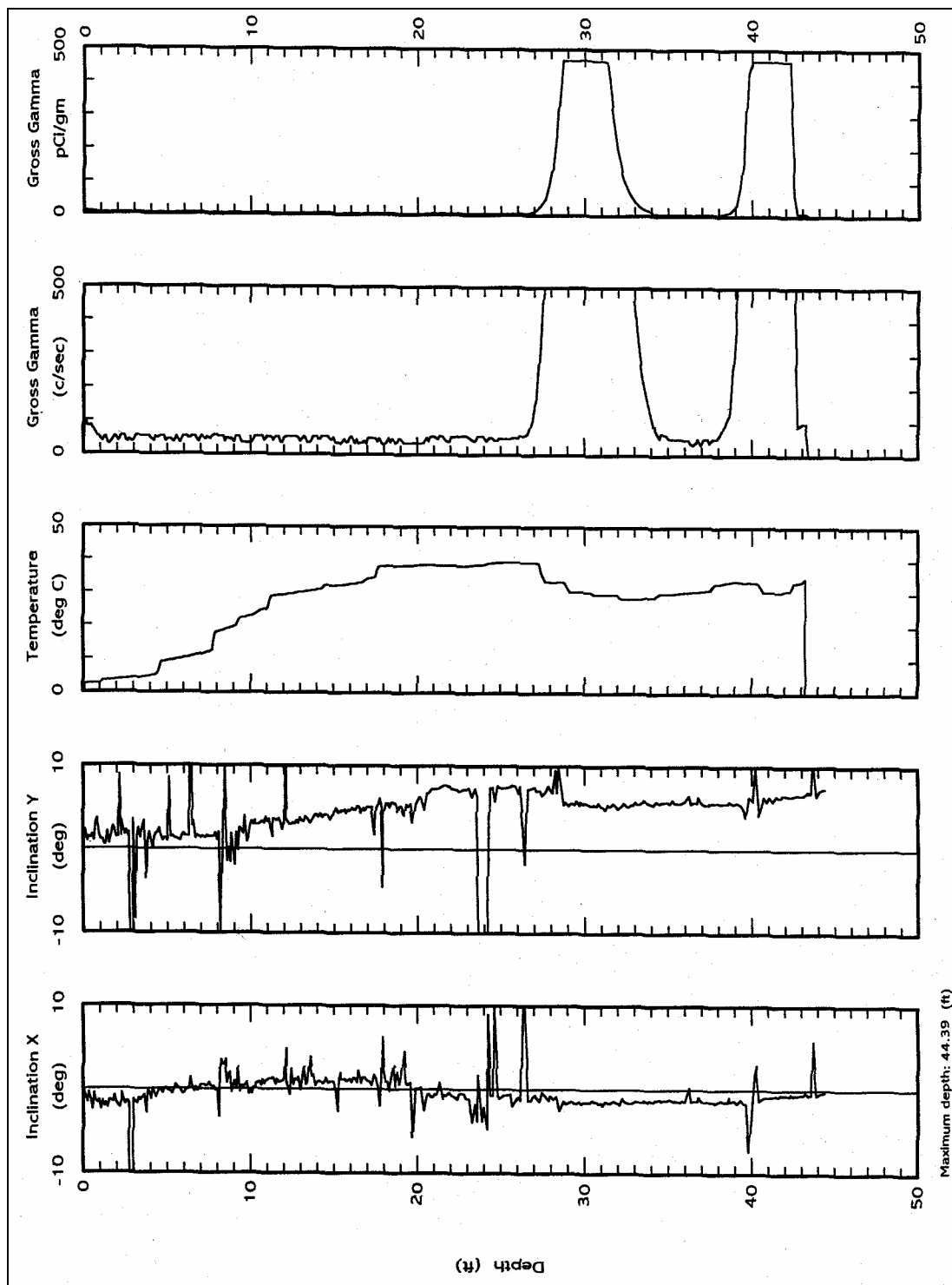
**Figure B.28. Dilution-Corrected Cation Content of Water Extracts and Cation Concentrations in Actual Porewater versus Depth for Borehole 299-W22-48**



**Figure B.29. Cone Penetrometer Test Locations in the S Tank Farm**

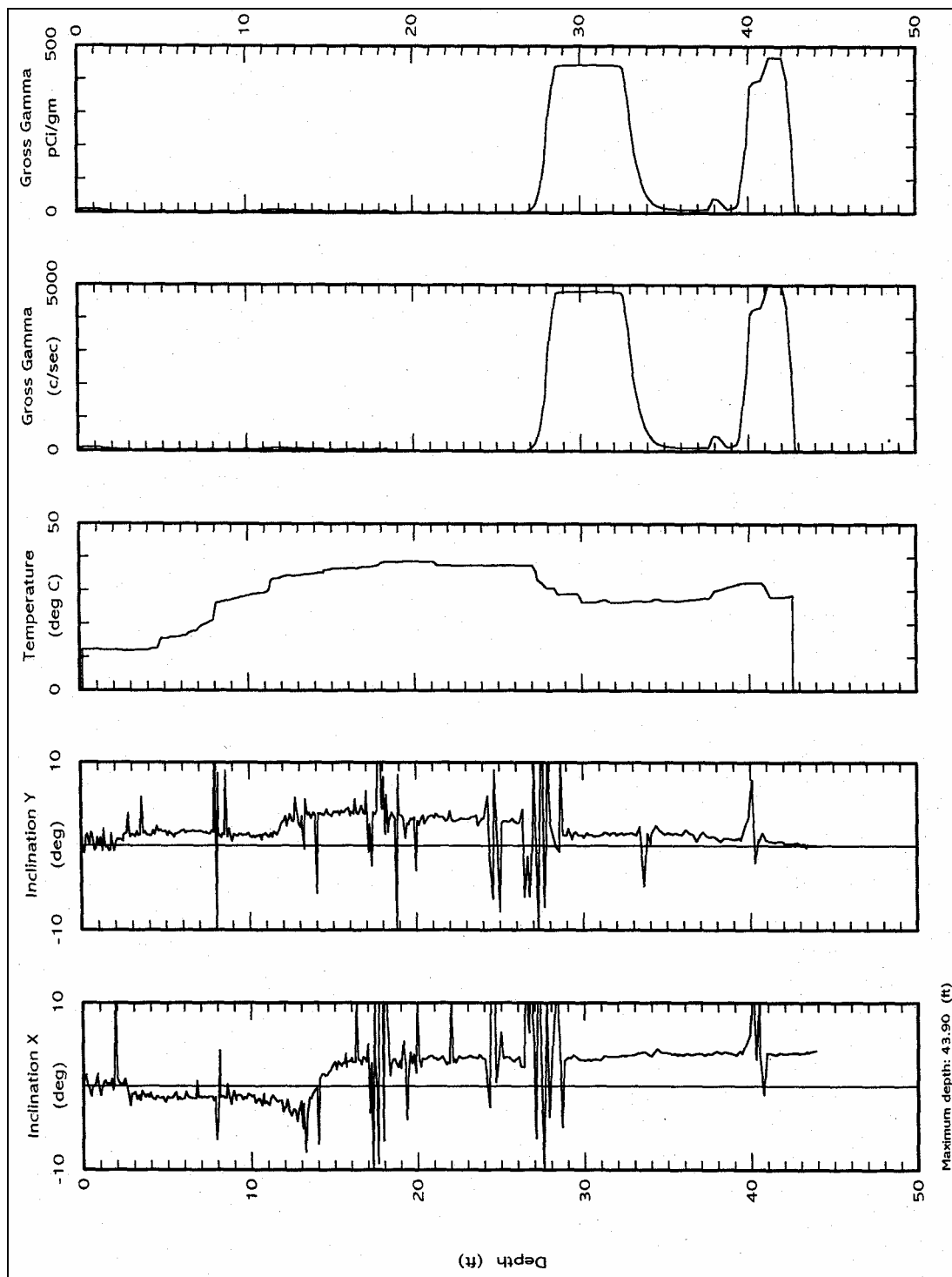


**Figure B.30. Distribution of Gross Gamma Concentrations at Location CP-04-04 Down to 50 ft (16 m) Below Ground Surface**





**Figure B.31. Distribution of Gross Gamma Concentrations at Location CP-04-05 Down to 50 ft (16 m) Below Ground Surface**



**Figure B.32. Estimated Extent of Shallow Contamination Zone Down to 50 ft (16 m) Below Ground Surface Near Tank S-104**

